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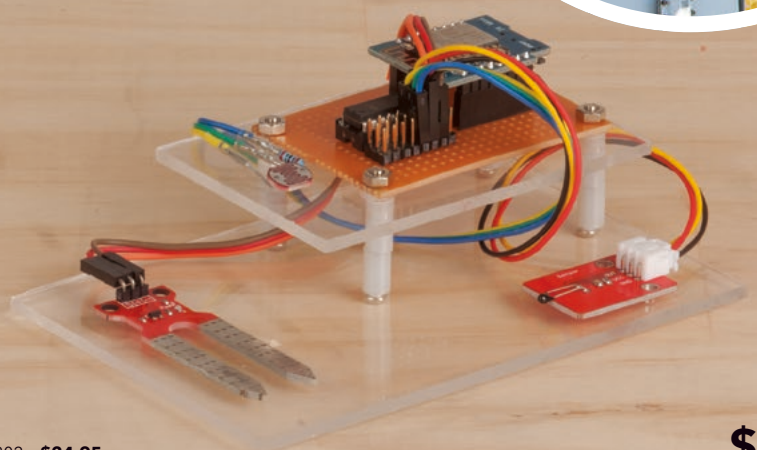

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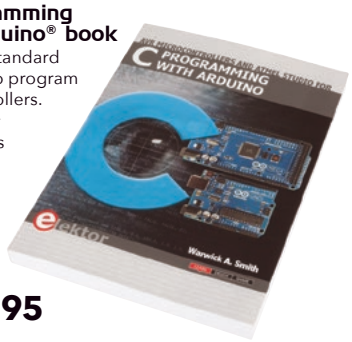

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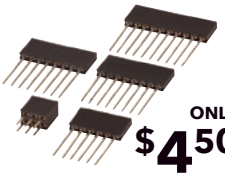

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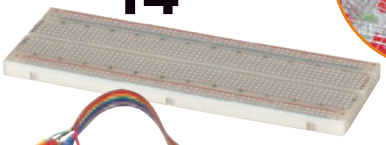

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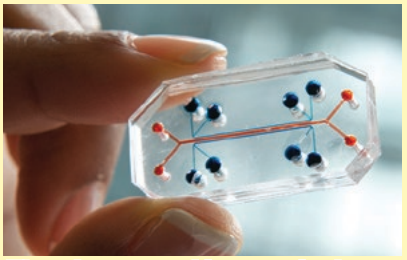

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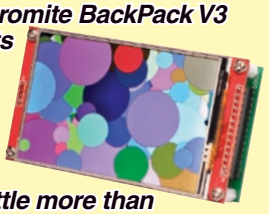

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Editorial Viewpoint

Jaycar Maker Hubs bring great possibilities

We have featured Jaycar's new Maker Hub on our front cover this month because we're excited about the possibilities that it opens up for our readers.

For some time now, we've been aware of the popularity of 3D printers but have been reluctant to design projects which require 3D printed parts because inevitably, some people who wanted to build those projects would not have access to a 3D printer. We could supply 3D printed parts, like we do laser-cut acrylic pieces, but that would require a significant investment of time and effort.

But now you can join Jaycar's free Nerd Perks program, rock up to their Maker Hub at Broadway and use one of their 3D printers to print just about anything you want at quite low cost.

And if the Sydney Hub is successful, we expect that more will open up, with at least one in every capital city – and ideally at least two or three in Sydney and Melbourne.

That will mean that we can start using 3D printed parts in our designs, confident that readers have a relatively easy and inexpensive way to produce them, even if they don't have access to a 3D printer themselves. And as they will soon have a laser cutter too, that means you can make custom versions of our case pieces and so on (eg, in a different colour).

The Maker Hubs should also be a great way to meet with and help (or get help from) other like-minded individuals, many of whom would also be Silicon Chip readers.

And as we've written in the introduction article (pages 27-29), we hope to host the occasional Q&A/tutorial sessions at our local Maker Hub.

New Micromite V3 BackPack will be the standard

The various versions of the Micromite LCD BackPack have been very popular since the first one was described by Geoff Graham in our February 2016 issue. The two main reasons for this great popularity – all around the world – are the colour touchscreen and the ease of programming and interacting with the touchscreen that MMBasic provides.

Once we'd designed the V3 BackPack, utilising the much higher resolution 3.5-inch touchscreen module, I was quite surprised to find that we could supply a kit for this new version for only a few dollars more than the V2 BackPack, which is itself only slightly more expensive than the original BackPack, despite having an onboard USB/serial converter and programming interface.

So given that you get a much nicer screen and more convenience for a relatively modest increase in price, I'm sure the new V3 BackPack kit will be the one to use from now on.

We will continue to supply the V1 and V2 BackPack kits with the smaller 2.8-inch screen, but I don't see us designing many projects around them any more.

The 3.5-inch screen is much clearer than the old one, and the BackPack with it still fits into a UB3 Jiffy Box. The new laser-cut lid is a little bit of a neater fit too, as it recesses inside the box itself, rather than sitting on top.

The V3 BackPack also has provision for several different onboard 'helper' modules and chips, most of which we can supply via our Online Shop, which makes it an excellent platform for experimentation and building simple microcontroller-based projects.

Check out the article, starting on page 30, for more details.

Nicholas Vinen

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Fluidics and the human eye

I notice that you are publishing an article by Dr Maddison on fluidics in this issue. One area not widely talked about is "Phaco Fluidics". This is the control of the microfluidic environment inside the eye during cataract surgery. The machines which control this are called "Phaco Machines".

I designed and built the only Phaco Machine ever made in Australia. Most Ophthalmologists (like myself) buy these from the USA, Germany, Japan etc. In the process of doing this, I wrote a book on the physics of fluidics.

Interestingly, much of microfluidics can be modelled with electrical equivalent circuits using SPICE. I got permission from Anasoft in the UK to use their software for this application.

There is no existing hydraulic software that can do it because the energy storage by elastic structures, fluidic inertia and transient effects are not well modelled in the usual hydraulic software.

In any case, the story of the Phaco Machine and the Fluidics eBook (available as a free PDF download) is on one of my websites:

www.worldmicrophaco.com

Dr Hugo Holden,
Maroochydore, Qld.

Suggestions for expanded RF Signal Generator project

The AM/FM/CW Scanning Signal Generator project by Andrew Woodfield in the June & July 2019 issue (siliconchip.com.au/Series/336) is a simple but very capable and elegant design. It offers excellent performance with a low parts count, small dimensions, low power consumption, simple construction, state of the art technology and very low cost. Yes, it ticks many boxes!

Modulated RF signal generator projects from all sources have been very few and far between in recent years, so my congratulations to Andrew and Silicon Chip for making this project possible. Given the solid basis of the design, may I suggest some ideas for an enhanced Mk2 version as follows:

- RF output ALC (automatic level control) to ensure stability of the RF level across its frequency ranges, and to ensure the output signal level remains calibrated at any frequency and any stepped/variable attenuator settings.
- A calibrated, stepped/variable RF output level attenuator, calibrated in volts/millivolts/microvolts/dB microvolts/relative dB.
- Adequate shielding of RF signal hardware, including attenuator, to minimise RF leakage into the device under test such that, hopefully, a selected RF output signal down to say 2-3µV is possible.
- A constant 50Ω output impedance regardless of the stepped/variable attenuator settings.
- Multiple touch-buttons to allow immediate selection of the desired AM/FM/CW/Scanning mode/submode options. These buttons could step through the parameters associated with their particular modes, simplifying the selection of the menus of interest.
- The ability to toggle the modulation on/off at the easy touch of a button for the AM and FM modes, with an on/off indicator.

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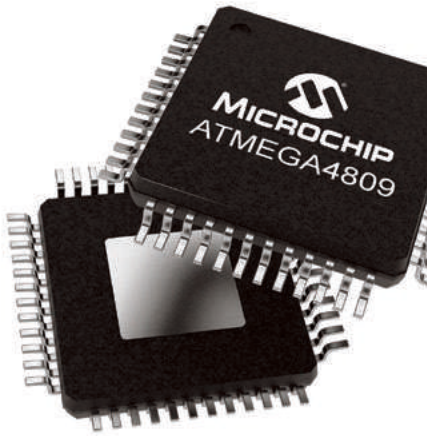

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• The ability to toggle the RF output on/off at the easy touch of a button, with an on/off indicator.

I realise these ideas would add to the complexity of the instrument, but they will also add significantly to its performance and capability.

Graeme Dennes,
Bunyip, Vic.

Andrew Woodfield responds: Thanks for the ideas, Graeme. Some others are noted at the end of Part 2, in the July issue. Improved attenuators can be added if suitable parts can be found.

Better screening is more difficult and requires metalwork often beyond the average reader, but µV-level tests are possible with the current design (with care). ALC and extra on/off switches will be considered for a future updated design.

Digital radio before DAB+

The DAB+/FM/AM Radio project in your January, February & March 2019 issues (siliconchip.com.au/Series/330) has rightly generated much interest, including from me. But I'm writing in because of another article in the February 2019 issue, on the BWD 216A hybrid bench power supply. It was of both nostalgic and historical interest to me.

Attempts for Australian digital radio broadcasting are not new and in fact, go back to the heyday of BWD and Australian electronic manufacturing in the early 1970s.

My first job in Australia (I arrived in 1973) was at AWA at North Ryde, in the research department as a technician. BWD was an unfamiliar brand of test equipment to me and in the following years, I used many examples of their equipment

My primary job was to assist with a digital frequency synthesiser being developed for military communications, for a system somewhat similar to an analog mobile phone. The prototype circuit had to be able to be 'microchipped', which AWA was capable of at that time. AWA was also making experimental optical fibre and I was required to come up to speed on this new technology.

At that time, the Australian government was considering introducing stereo radio. It had tried using the standard VHF FM system some years earlier, but that was later abandoned. AWA proposed a digital UHF system; I guess hoping that it would be used Australia-wide and they would have a head start in receiver manufacture.

As we know, the government opted to go back to the standard FM system we are now slowly phasing out in favour of DAB+. My senior engineer and I were involved in some work on the Australian non-standard VHF TV channels, and the possible reallocation of these channels to accommodate the proposed new systems.

Whilst there are some notable exceptions of Australian advanced electronic manufacturing, such as CEAFAR phased-array 3D radar and the like, electronics on a grassroots level has all but disappeared. Perhaps Dr Maddison should write an article on CEAFAR and other current significant Australian electronic projects. Australia needs all the push it can get to reestablish advanced manufacturing work!

Kelvin Jones,
Kingston, Tas.

RF Signal Generator 6m amateur band gap

Congratulations on a potentially most useful project in the AM/FM/CW Scanning HF/VHF RF Signal Generator. However, it is unfortunate that there is a gap in frequency coverage, particularly when the gap covers the 6m amateur band, making the Signal Generator of somewhat limited use for many radio amateurs.

And one questions the use of an SMA connector rather than the more robust industry standard BNC, which still operates perfectly satisfactorily at 150MHz.

Antony Bell,
Broadview, SA.

Andrew Woodfield responds: you make a valid point about the generator's coverage. The design does provide continuous coverage up to 150MHz, including all of the 6m band.

The generator cannot meet the claimed specifications on some frequencies; for example, around 62.5MHz (half the 125MHz DDS clock frequency) and from 120-130MHz, where the output level falls sharply.

But it does still provide useful CW, AM and FM outputs across the 6m band. Most amateur receivers will cheerfully reject the aliasing products. However, users would need to take much greater care with testing, especially with sensitivity and blocking measurements, as well as basic alignment.

Substituting an AD9851 module and using a higher clock frequency would improve this, but that would make its performance worse at the low-frequency end. That's still an option, as the alternative filter on the circuit diagram suggests. The software does not currently support the AD9851 module, but if there is sufficient demand, a modified version of the software could be made available.

A BNC connector was considered and in fact, the second prototype was built with one, but the lightweight generator was routinely pulled around the bench by the heavy BNC

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coaxial cable tail! The SMA connector solved that problem and also made it cheaper and easier to build. The PCB provides space for other connectors to be fitted, with care.

SMA connectors are becoming something of a standard for amateur (and professional) equipment in recent years. They are significantly less expensive and more compact than BNC and many other types. I use both interchangeably on my bench, along with N-type and, occasionally, the PL-259/SO-239 types.

Despite my initial reluctance to use them, I quickly found SMA easier to use and more reliable in practice for testing than BNCs. When using the generator with BNC equipment, I use a low-cost, 300mm-long SMA-to-BNC RG-213 cable tail on the generator output. It also limits the generator excursions about the bench.

You can get SMA/BNC connector adapters, but I find them less useful. They can place an undesirable lateral strain on SMA connectors. Both cable tail and adapter options are available for less than $3 online.

All-in-one Time Domain Reflectometry (TDR) device

Congratulations for your continuing excellence in the projects presented by Silicon Chip magazine.

I was browsing through some back-issues and came across the Dead-easy Superhet DDS IF Alignment project from September 2017 (siliconchip.com.au/Article/10799), which was based on the Micromite LCD BackPack with a touchscreen. This made me think about a project where such a similar device could be used to detect cable faults.

The TDR Dongle for Fault Finding from the December 2014 issue (siliconchip.com.au/Article/8121) is great, as it allows you to figure out where along a transmission line a fault has occurred. It does this by injecting a signal, and you then look at the delay and shape of the 'echo' from the fault (open/short/kink/etc).

But you need a scope to use it, and that can be really inconvenient if the cable is in a conduit, or buried in the ground, or just too long to drag into your lab.

How about instead designing a new TDR device using the Micromite LCD BackPack, so that you just plug it in and away you go? I feel the Micromite and the touchscreen combination would be an ideal way to provide such a facility.

William Spedding,
Lake Cathie, NSW.

Response: that is an excellent idea, especially when you consider the updated Micromite LCD BackPack V3 published in this issue on page 30, with its larger and higher-resolution screen, which would do a great job of showing the TDR waveforms.

A Battery Isolator which doesn't exactly isolate

I just read your High Current Dual Battery Isolator project article in the July 2019 issue of Silicon Chip (siliconchip.com.au/Article/11699).

Some time ago, I bought a commercial isolator unit and about the first thing I noticed was that there was only isolation from the charging side to the load when off. There was an inherent diode connection from the load back to the main terminal, so current could flow from an auxiliary battery back to the starting battery.

That's not good, particularly when starting, as the starting battery voltage can drop significantly, causing quite a bit of current to flow through the isolator in reverse. As a result, I now only use that unit as a low battery cut-out.

It's good to see that Bruce Boardman was aware of this problem and designed the circuit accordingly, although I haven't quite worked out how current can flow either way in a Mosfet. As a result, I am tempted to build that unit.

By the way, what happened to the new beaut linear power supply you were advertising as coming next month a few times, several months ago? Keep up the good work.

Brian Playne,
Toowoomba, Qld.

Response: The easiest way to think of a power Mosfet is as a diode in parallel with a variable resistance. When the Mosfet is off, the resistance is very high, and when it is on, it is very low.

So current can always flow in one direction when it's off (with significant losses, as the body diode is not terribly efficient), and when it's on, the channel effectively shorts the diode out (except perhaps if the channel resistance and current are relatively high), so current can flow through it in either direction.

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The body diode is reversed in P-channel Mosfets compared to N-channel, as is the gate-source voltage polarity (positive to switch an N-channel on, negative to switch a P-channel on).

Regardless of type, if you connect a pair of power Mosfets drain-to-drain or source-to-source, the body diodes will face in opposite directions and the resulting structure can block or allow current flow in both directions, although the total resistance and therefore heating/losses are doubled.

Regarding the linear power supply, we are still working on it. It has taken a bit longer than expected, but we're in the process of building what will hopefully be the final prototype. Assuming that works well, the first article on the new Bench Supply should appear in the October issue or thereabouts.

Note that the "Coming up in Silicon Chip" section of the magazine does not promise that the articles mentioned will be in the next issue. It says "Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip". Admittedly, in this case, it has been a while since the new project was first mentioned.

Household Earthing can be dangerously inadequate

For a long time, I have known the importance of plumbing to the electrical Earth (MEN) system, and I believe Silicon Chip even wrote about it. I remember that it was mentioned that plumbers often use jump cables when cutting pipe in the roof and changing water meters to avoid electrocution.

The other day, I had a burst main pipe from the meter to house. When I located the leak and dug it up for the plumber, I found that the copper pipe from the meter was joined to a PVC pipe 1.5m from the meter, which then re-connects to a copper pipe further on.

I have the normal Earth wire which is fixed to an outside tap and a stake into the dry sand. To me, this is not a brilliant idea, and I guess this is why I get a tingle at times when barefoot on the bathroom tiles. The plumber told me that my installation is legal and the electrician told me it should be OK. But I do worry about the impedance of dry sand.

This inadequate way of doing things may have been a factor in the accident in Heathridge. Electrical safety is a priority and must be taken seriously.

Howard Maddaford,
Wanneroo, WA.

Nicholas responds: You are right that this has been discussed in the magazine in the past. You are probably thinking of Leo's article in the August 2014 issue, "Your House Water Pipes Could Electrocute You!" (siliconchip.com.au/Article/7966). It was also the topic of his editorial in that same issue.

Leo's follow-up editorial in the September 2014 issue (siliconchip.com.au/Article/7993) is particularly relevant to your situation.

My suggestion is to get a friendly plumber to replace that PVC pipe with copper, or get a thick copper wire to bridge the gap (or even several), securely clamped to the pipe at both ends. As you say, depending on the type of soil, the Earth stake can't always be relied on to provide a low resistance connection.

My Earth stake at home is buried in concrete. I wonder how effective it is, given that the concrete must limit rainwater reaching the soil below.

Magazine price hasn't changed in years

Dear Silicon Chip Staff, thank you for the great range of electronic projects and topics covered in your magazine. Over the years, I've built many of your audio/visual projects. Including the DAB+ Tuner kit and the fantastic sounding Majestic speaker, deleting the tweeter and turning it into an awesome sub-woofer powered by the CLASSiC-D amplifier kit.

While I don't always have an immediate need for many of your projects at the time of publication, I find myself frequently referencing your magazines for a past project to meet a new need. Sometimes, the project will date back ten or so years ago.

I'm thinking of building the WiFi Water Tank Level Meter from the February 2018 issue (siliconchip.com.au/Article/10963), but there are some aspects of the earlier November 2007 Water Tank Meter project that better suit my particular needs.

Being able to read the articles for an understanding of the technologies used tremendously assists me in deciding if a project is suitable.

For me, the main attraction of both these kits is being able to monitor multiple tanks, which is something I've not seen in readily available mass-produced units. So thank you for having

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the foresight to include this feature. It's almost like you knew I would need it even before I did.

When looking through my library of back-issues, I noticed that the last time you had a price increase was March 2013. Even then, the cover price only went up by 65¢.

So another round of congratulations for maintaining the value readers get for such a long time. Hopefully, this is something which can continue for a while yet before things like rising power prices force a review.

I sincerely mean every word of thanks. Over thirty years, your magazine has developed my electronics knowledge, facilitated the enjoyment of my hobby and enhanced my lifestyle through useful projects.

Tim Herne,
Batehaven, NSW.

Response: as you say, costs have risen significantly over the six and a half years since the last price increase. We've done everything possible to avoid having to put up the price again.

We don't want to lose any readers and like to think that the magazine is good value. Not only have we kept the price the same, but we're providing readers with more content than ever; most issues these days are 112 pages, despite the number of ads remaining much the same as before.

But eventually, we will have to increase the price to stay in business. We will try to put that off for as long as possible.

EA magazines being given away

As I am downsizing, I have to unload a complete collection of *Electronics Australia* magazines from 1979 until its descent into oblivion about 2004, and Silicon Chip since then. I'm also giving away other miscellaneous items of electronic literature. They are yours free of charge if you're willing to collect them in the Geelong area.

Charles Close,
Geelong, Vic.

Editor's note: interested readers can e-mail us and we will pass it on to Charles.

New DIY digital oscilloscope kit

Readers who were intrigued by Jim Rowe's article about the JYE Tech DSO138 Oscilloscope in the April 2017 issue (starting on page 53, see: siliconchip.com.au/Article/10613) may be interested to know that an improved version is now available. It is the DSO150, and it also comes in kit form. Like its predecessor, it is also available from Banggood in China and costs the same at around $30.

While the heart of the instrument (the software) is clearly the same, the appearance and functionality is a vast improvement. Instead of the ugly transparent acrylic case, it is enclosed in a smaller moulded case which is quite attractive. The vertical sensitivity is now selected in software instead of by those two fiddly slide switches; there are now 12 steps from 5mV/div to 20V/div.

It is more user-friendly to make adjustments. Instead of having to press the SEL button multiple time to move the parameter selection anti-clockwise around the display, you just press one of three buttons and then make the adjustment with a rotary control. In other words, it works more like a full size (and full price) DSO.

The performance is the same as the DSO138; frequency response is flat to 100kHz (not 200kHz as claimed). The -3dB bandwidth is 150kHz, but aliasing precludes accurate waveforms above 100kHz.

Ross Stell,
Kogarah, NSW.

DMM test leads can have high resistance

I tried to measure the power consumption of a 3W LED power circuit recently and the difference between the presence and absence of a digital ammeter measuring current consumption at 1W output was some 50mA; far worse than the ammeter's "burden voltage" described by Rodger Bean (thanks, Rodger) in Circuit Notebook, December 2018 (siliconchip.com.au/Article/11343).

It then struck me that there must be additional and significant resistance in the DMM leads to produce such a difference. I have a capacitor ESR meter (MESR-100 100kHz In-Circuit Tester) which is also capable of accurately measuring low resistances from virtually zero up to 100Ω.

So I measured the resistances of all the DMM and other test leads I possess (some 20 in all). Most measured between 0.5Ω and 0.8Ω. So two leads would have a series resistance of as much as 1.5Ω, possibly more.

Even the high-quality silicone-covered leads of my prize possession, a new Digitech QM1323 meter, measured around 0.6Ω each, for a total of 1.2Ω.

Resistance understandably increases with lead length, and at 900mm, some of the commercial leads are too long in my opinion. The lowest resistances I measured of 0.14-0.15Ω were of the shortest leads, around 200mm long. Part of the problem is the relatively thick insulation required to meet the voltage ratings, and make the leads sufficiently robust, leaving little room for copper inside.

So I think anyone making this type of measurement should buy or make short, high-quality test leads and remember to take their resistance into account when measuring current, and the effect that has on the voltage across the device under test.

Colin O'Donnell,
Adelaide, SA.

Response: the test lead resistance can indeed be orders of magnitude higher than the shunt resistance in an ammeter. For example, if you're charging a sizeable lead-acid battery from a power supply set to 14.4V using regular clip leads, the battery terminal voltage can be well below 14V until the charging current drops significantly due to lead resistance. The leads can get pretty warm, too!

Electronic medical records have advantages

Congratulations on the quality of Silicon Chip magazine. At 83, I can no longer compete in soldering competitions, but Silicon Chip enables me to keep up with what is happening in electronics. Thank you very much!

In January 2018, we were cut across

to the NBN (FTTN). Our home security system was connected to the terrestrial phone line, and had been reliable, but was beginning to give the occasional false alarm. The system dated back to the mid-90s, so was due for a major overhaul.

The security company told us that our old system was not compatible with their new methods of networking post-NBN, so we upgraded. The new system seems to be quite reliable after almost 12 months' service. It is totally wireless, that is, the internal motion sensor connections and the connection back to the base in Sydney are all wireless, and so far as I am aware, outside the NBN.

I agree with other correspondents that there are dangers inherent in the giving over of personal information to third parties, but there are advantages too. Around fifteen years ago, my wife had hip surgery. This meant she had scans, anaesthesia, sedation and things like blood grouping done. This info was kept in the ACT health database.

Some years later, on New Year's Day (a public holiday), she had a tumble while out walking and broke an ankle, quite seriously. She told me later that she was aware while in the ambulance that the ambos had all that information available in the vehicle. It made processing her case through A&E very fast, and sold us on the value of health databases!

She was able to communicate and confirm details, but what if she had been unconscious after a more serious accident? The availability of this information could have been critical.

Bruce Bowman.
Canberra, ACT.

New Battery Capacity Meter suggested

My son is setting up his ute for camping. Who isn't? He is fitting an auxiliary battery and has been looking at the various battery managers on eBay. It seems there are all permutations and combinations available.

What I think would be an interesting project would be a measuring 'head' attached to the battery, which would measure current and voltage. A PIC could then keep track of the current flowing in and out and calculate the residual capacity, for example. This data could then be sent via Bluetooth to a mobile phone for data readout.

Peter Trigg,
Montrose, Vic.

*Response: we published a Battery Capacity Meter in the June & July 2009 issues (**siliconchip.com.au/Series/44**), but while it worked, it was a bit of a monster. It's definitely a concept worth revisiting, but it could take quite a lot of development work. Don't expect to see a revised design until the beginning of next year at the earliest.*

NBN critics missing the point

I find the ongoing criticism of the FTTN version of the NBN surprising. We have had FTTN NBN for a year through a stock-standard basic Telstra plan and have had entirely reliable 50/38Mbps where the node is a minimum 500m from our home (the end of the overhead cable run).

This demonstrates that FTTN is a more than adequate technology and so any difficulties experienced are either fault-conditions or unrelated to FTTN (and therefore not a justification for inclusion in the FTTN/FTTP debate).

Further, I question the many demands that require FTTP to facilitate "working from home" when such "working from home" has, to my decades of experience, been well-served by borderline ADSL (our previous service) and a web browser linking to the workplace.

Few "working from home" scenarios would require anything more than a 'thin client' type service (providing only a view of the screen with a keyboard/mouse back-channel), and those who might wish to move massive volumes of information that might justify FTTP can justify paying a few thousand dollars for a custom installation.

I also note that many of the criticisms of the current FTTN NBN come from areas serviced by the rural-level of service – an area that was not, even under Labor's grandiose plan for the NBN, going to get 100Mbps. Yet the complaints about the LNP version of the NBN (the FTTN bit) continue to abound even though those rural areas are still getting the service that Labor planned.

Such complaints are therefore a misrepresentation of the issues and an unfair criticism of the LNP's efforts to make yet another Labor fiasco actually work.

It is long past time that the true differences between the Labor and LNP versions of the NBN were fully documented and the actual relative cost calculated. I note that despite having many installations completed before the 2013 election, Labor refused to release figures on cost-per-installation. It is time that those figures were released and an accurate comparison made.

John Evans,
Macgregor, ACT.

Nicholas responds: I agree that arguments over whether FTTN is better than FTTP and so on are pointless, as it isn't the "last mile" technology that's the problem.

From the day the NBN was announced, my criticism has been that it put too much emphasis on these user connections and not enough on the backbones, which were already congested in 2007. Giving users faster connections only made that worse.

You're right that ADSL is probably good enough for working from home, giving a reasonably symmetrical connection.

The biggest flaw with ADSL is that it allocates too much bandwidth for downloading and not enough for uploading; uploading then severely interferes with the ACK packets needed for downloading, so uploads are not only slow but they can cause the connection to grind to a halt.

NBN FTTN is essentially a VDSL2 service which solves this by having a much more symmetrical bandwidth allocation, eg, 50Mbits down/20Mbits up.

We were forced onto the NBN at our office about a year ago, and while it's faster sometimes, overall it's slower than our old ADSL connection. It's not the line that's the problem; it's the network congestion which is getting out of hand. The line is fast but the congestion is so bad that latency is poor; DNS lookups are slow, and as a result, web pages load like treacle.

I don't see the point in trying to allocate blame. The NBN was poorly conceived, and it was clear from day one that it was never going to reach the stated performance goals without a massive blowout in cost. I predicted on the day it was announced that it would cost at least $100 billion all up (when they said $43 billion). I reckon I wasn't far off.

The question now is how to overcome these problems, and in my opinion, the only solution is an extensive (and expensive) overhaul of the backbones, including international links, to handle the increased traffic. SC

You have probably heard about the mechanical computers built before the electronic age. But did you know that computers and 'circuits' based on fluid flows have been built and used since the late 50s? You've probably used one; until recently, most automatic transmissions used oil-pressure logic to select gears. And now "microfluidics" brings more options for logic and analog signal processing.

Fluid logic, Fluidics and Microfluidics

Fluid logic, known as "fluidics", was a concept that came about during the late 1950s and was heavily researched in the 60s and 70s. Like electronics, these devices have no moving parts; they use fluids (liquids or gases) to perform similar functions to the electrons in electronics.

Typically, the fluid moves through channels etched or machined in a solid block of material, such as metal or plastic.

The functions provided can be analog or digital in nature. For example, a fluidic device could provide amplification (analog) or perform boolean logic operations (digital).

Devices that incorporate fluidics and also use moving parts, such as valves or electronics, are known as hybrid systems.

As mentioned above, the example you're most likely to be familiar with is an automatic transmission; the controlling 'valve body' is a hybrid device – see Fig.1.

Other examples of fluidic devices in widespread use today are devices that provide pulsating streams of water, as used in some shower heads and hot tub jets which employ "fluidic oscillators". Electrical or electronic implementation of these same functions would be expensive, complicated and require electrical wiring.

Certain windscreen washer nozzles generate a moving spray pattern using fluidic effects; "flapless" aircraft control systems also use fluidics.

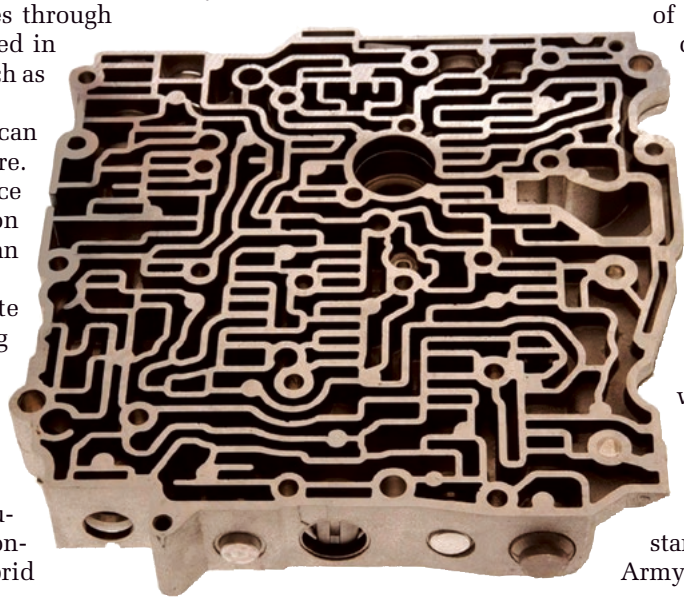


Fig.1: the valve body from an automotive automatic transmission. The numerous passages that are filled with transmission fluid work as a fluidic computer, to make decisions as to when or if to shift gear and to direct fluid, via valves, into the appropriate clutch pack or band servo. Newer automatic transmissions are controlled by a computer using solenoids in the valve body.

Ordinary hydraulic devices such as hydraulic cylinders are not considered to be fluidic devices.

The initial motivation for developing these devices was due to the Cold War. There was pressure between the West and the Soviet Bloc to produce devices that were resistant to the effects of electromagnetic pulses and radiation from nuclear explosions.

Fluidics offered a solution to this problem (see Figs.2-5).

Later, these devices were adopted for more peaceful uses due to their robustness, in applications such as industrial automation.

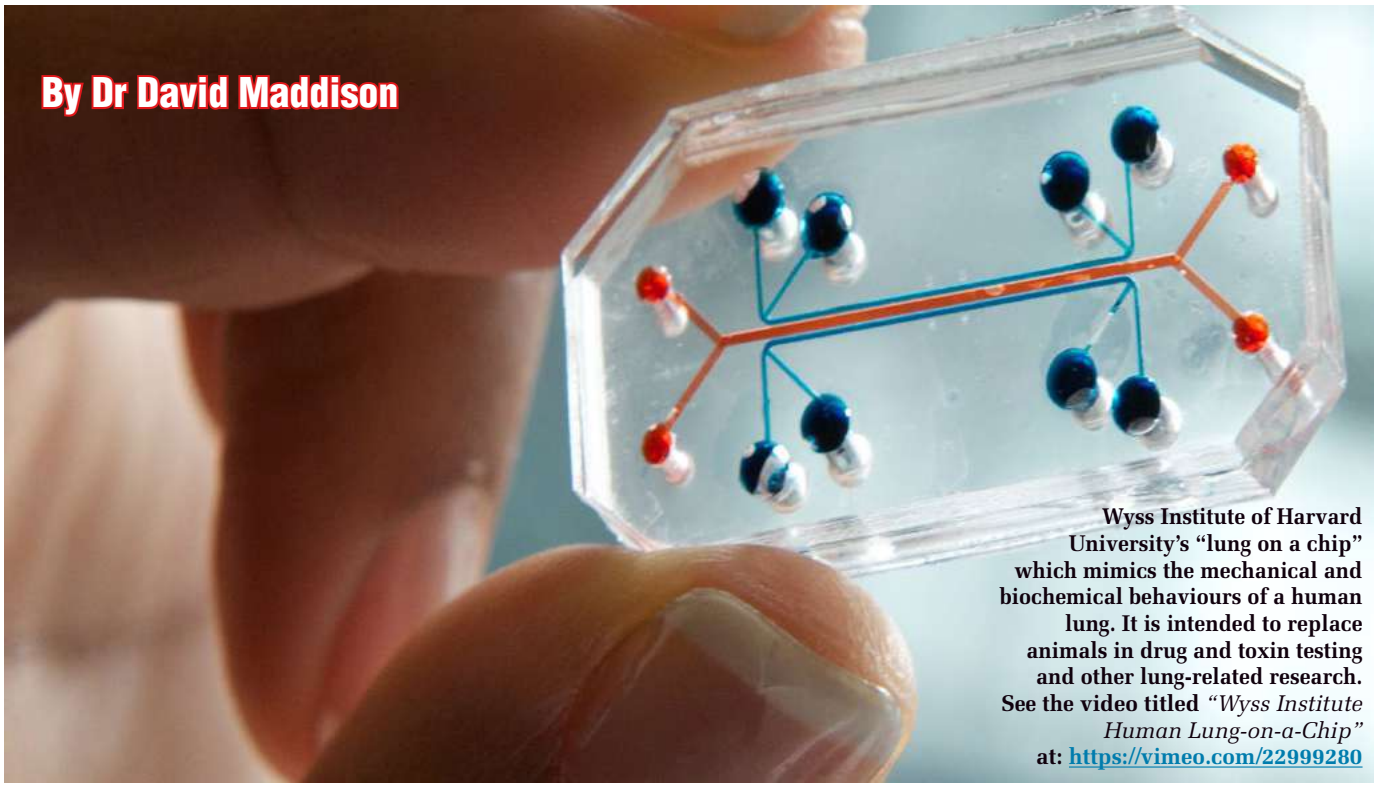
But with the rapid development of military and civilian-grade electronics that could withstand the effects of nuclear war and the rigours of industry, they became mostly obsolete some time in the 1970s, and few people know of them today.

Fluidics is considered to have started in what is now known as the Army Research Laboratory in Maryland, USA.

In 1957, Billy M. Horton invented the fluidic amplifier (then called fluid amplification).

In 1959, Horton and colleagues R. E. Bowles and Ray

By Dr David Maddison



Wyss Institute of Harvard University's "lung on a chip" which mimics the mechanical and biochemical behaviours of a human lung. It is intended to replace animals in drug and toxin testing and other lung-related research. See the video titled *"Wyss Institute Human Lung-on-a-Chip"* **at: https://vimeo.com/22999280**

Warren developed a range of such devices, and this attracted widespread industrial and military interest.

There are earlier patents on fluidic amplifiers from the 1930s and 1940s, but these attracted little attention at the time.

The development of fluidic systems peaked in the 1960s and 1970s, and NASA produced a list shown of systems that had been successfully implemented as of 1972 – see Table 1.

Compared to electronic devices of the time, fluidic devices were slow and operated at no more than a few kilohertz.

They were smaller than equivalent electromechanical components such as solenoids and relays, but much larger than electronic equivalents.

In practice, no more than three fluidic elements could be connected in a chain, but they were very robust compared to electronics of that era.

Apart from some niche applications for traditional fluidics, which are described below, there has in recent times (since the 1980s) been a revival of interest in fluidics. But interest is now in a different area, known as "microfluidics".

Microfluidics is mostly used in biotechnology, but also in some other areas. It involves the manipulation of tiny

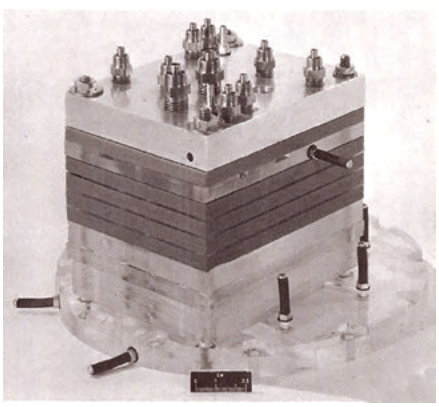


Fig.2: a fluidic 'integrated circuit' logic device (stepper motor actuator) for a nuclear rocket motor from a 1972 NASA document. Fluidics was chosen for this device as it was to be placed next to the nuclear fuel in a high radiation and heat area.

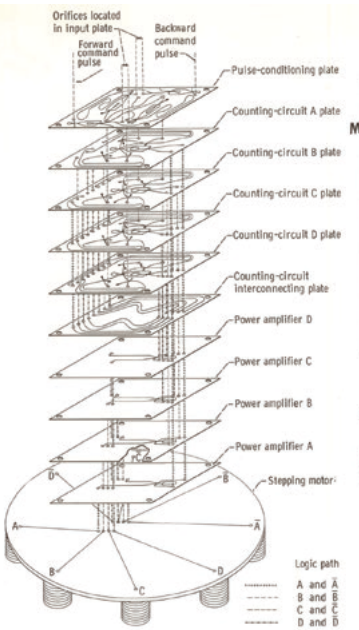


Fig.3: an exploded view of the stepper motor actuator shown in Fig.2.

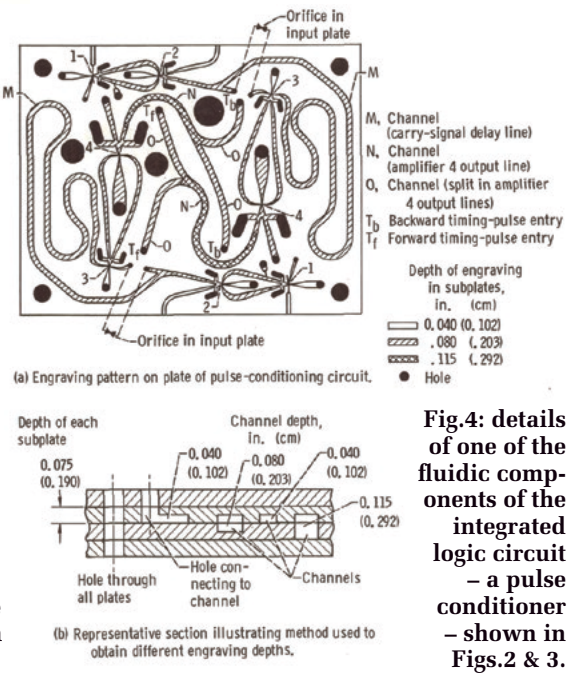

Orifice in input plate
M, Channel (carry-signal delay line)
N, Channel (amplifier 4 output line)
O, Channel (split in amplifier 4 output lines)
Tb Backward timing-pulse entry
Tf Forward timing-pulse entry
Depth of engraving in subplates, in. (cm)
0.040 (0.102)
.080 (.203)
.115 (.292)
Hole
(a) Engraving pattern on plate of pulse-conditioning circuit.
Depth of each subplate
0.075 (0.190)
Channel depth, in. (cm)
0.040 (0.102)
0.080 (0.203)
0.040 (0.102)
0.115 (0.292)
Hole through all plates
Hole connecting to channel
Channels
(b) Representative section illustrating method used to obtain different engraving depths.

Fig.4: details of one of the fluidic components of the integrated logic circuit – a pulse conditioner – shown in Figs.2 & 3.

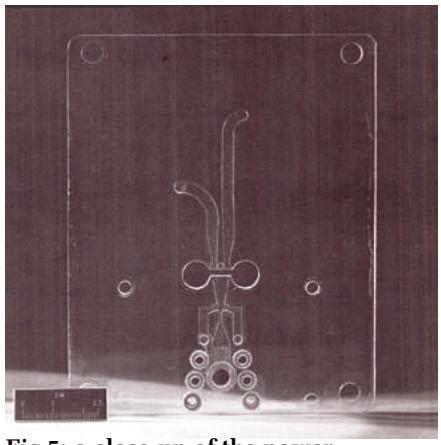


Fig.5: a close-up of the power amplifier plate, "Power amplifier D" from the NASA fluidic integrated circuit (Figs.2-4). Note the scale.

amounts of liquid, typically in the picolitre (10^{-12}l) to microlitre (10^{-6}l) range.

To visualise a picolitre, it is the volume of a cube measuring just 0.01mm on each side!

Examples of microfluidic devices include "labs on a chip", DNA microarrays, inkjet printer heads and some micropropulsion devices for miniature spacecraft.

Basic principles of fluidics

Fluidics utilises the interaction of gas or liquid streams in appropriately etched or otherwise shaped constraining structures.

These can provide sensing, computing, amplifying and controlling functions, generally without moving parts. These devices are therefore simple, robust and reliable.

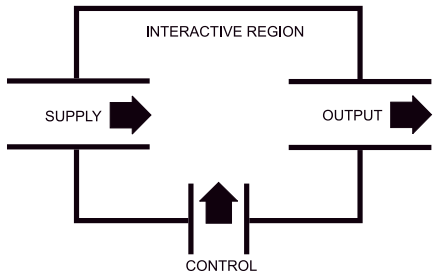


Fig.6: an idealised representation of the basic parts of a fluidic device. The output of the device is dependent upon what happens in the interaction region. *Source: NASA.*

Most fluidic amplifying or control devices have four basic elements: a supply port, an output port, a control port and an interaction region (see Fig.6).

In terms of a vacuum tube equivalent, these elements would be, in order, the cathode, plate, grid and the interelectrode region. With greater device complexity, there may be more ports.

The behaviour of the fluidic device is governed by the types of fluid dynamic phenomena that occur in the interaction region.

The three main types of effects that occur are:

1) **Jet interaction,** where an unconstrained stream of fluid (the supply jet) is influenced by a control flow which moderates it.
2) **Surface interaction**, where the supply jet interacts with a surface. This includes the Coandă effect, which refers to the tendency of a stream of fluid near a surface to attach to that surface and to remain in contact with it, even though the direction of the surface is different from the initial flow of the stream.
3) **Vortex flow,** in which a vortex, or tendency to form one, influences the device function.

Fig.7(a) shows an example of a logic device that uses jet interaction. It is an AND/XOR logic gate.

The output of an AND gate is high (on) if both inputs are high (on) while the output of an XOR gate is high (on) if one input is high (on) and the other is low (off).

The first picture shows the device with no fluid. At the top there are two channels; one is for the supply and the other may be considered the control channel. In the middle, there is a "bucket" which forms the AND gate. It collects (or doesn't collect) streams of fluid and has its own output connection. At the bottom of the device, there is another output to collect (or not) a stream of fluid, and this is the XOR gate output.

Fig.7(b) shows how, with fluid applied to one of the inputs but not both, it can pass through to the output at the bottom, giving the correct result for an XOR gate.

But as shown in Fig.7(c), if both input streams contain fluid, the two streams collide and the fluid is col-

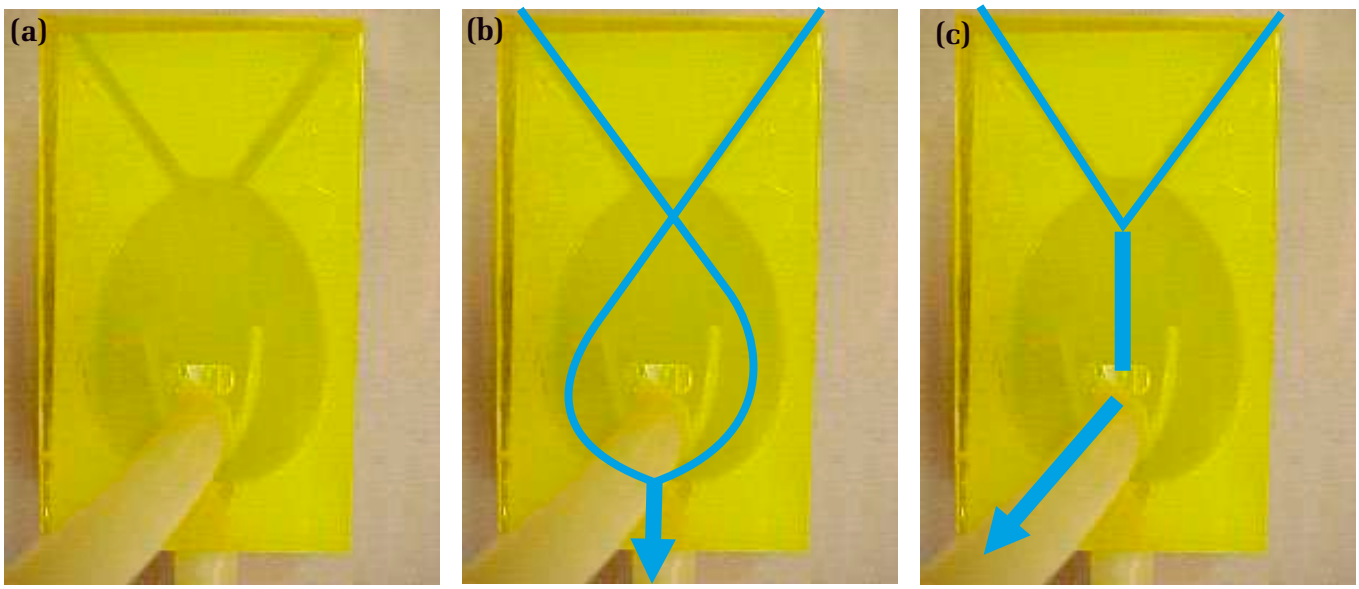


Fig.7: a fluidic logic AND/XOR logic gate, using jet interaction. If one of the input streams contains fluid but not the other, that fluid flows out the bottom. But if both streams contain fluid, they collide and collect in the upper bucket, and exit through the separate hose. *Source: Paulo Blikstein.*

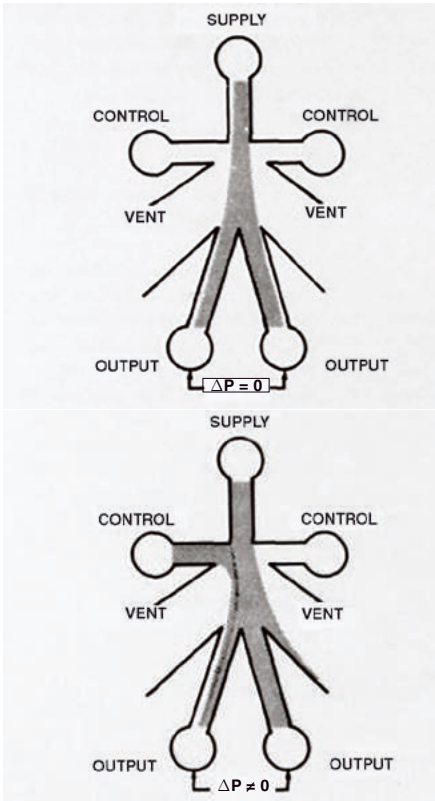


Fig.8: a jet deflection fluidic proportional amplifier. *Source: J.W. Joyce and R.N. Gottron, US Army, HDL-SR-77-6.*

lected in the AND bucket and flows through the upper output tube, giving the correct result for an AND gate.

Examples of devices which use surface interaction (fluidic thrust vectoring) and vortex flow (spray nozzles, flow rate metering and massage chair control) are given below.

Fluidic element examples

As mentioned above, fluidic elements can perform analog or digital functions. Here are some examples of both, but note that this is only a small subset of the fluidic designs which exist.

A jet deflection fluidic proportional amplifier is an analog device in which a supply jet is diverted from one output port to another, depending on the flow coming from one of the control ports.

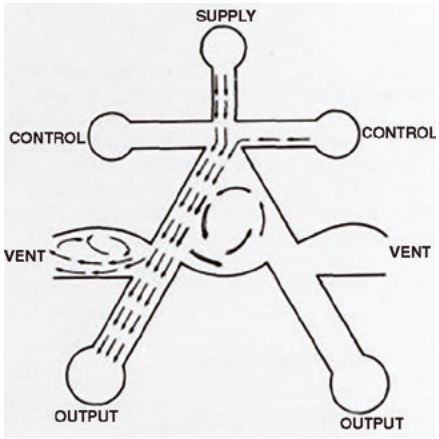


Fig.9: a wall attachment fluidic amplifier. *Source: J.W. Joyce and R.N. Gottron, US Army, HDL-SR-77-6.*

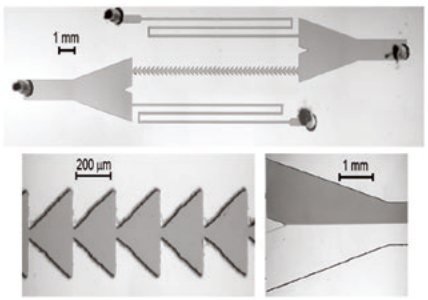


Fig.10 (above): a microchannel fluidic diode (note the scale). The diode element is the chain of triangular channels. The direction of highest flow resistance is from right to left, which may seem counter-intuitive. Nikola Tesla patented a similar device called the Tesla valve in 1920. *Source: Graydon Yoder et al, Oak Ridge National Laboratory, ORNL/TM-2011/425.*

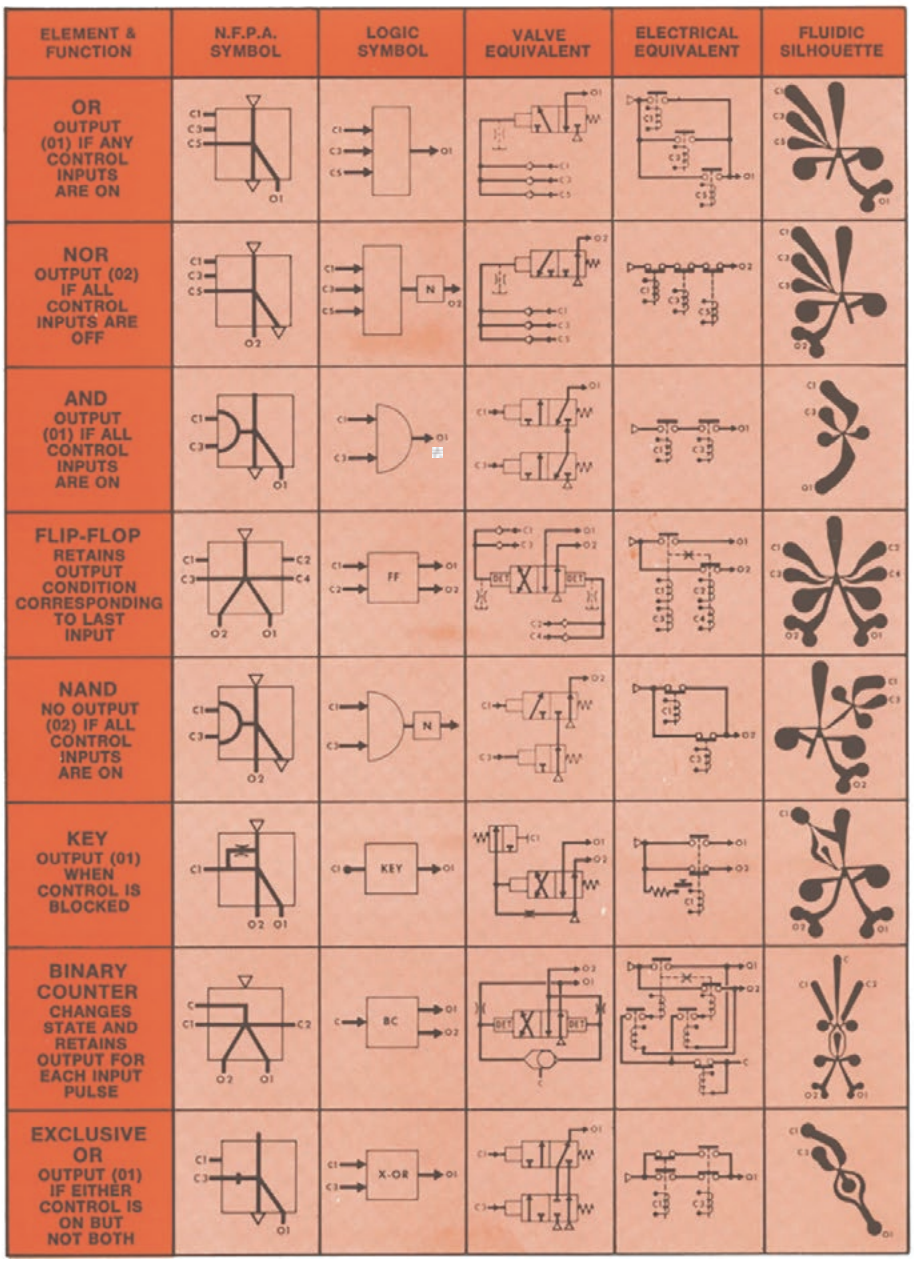

ELEMENT & FUNCTION
N.F.P.A. SYMBOL
LOGIC SYMBOL
VALVE EQUIVALENT
ELECTRICAL EQUIVALENT
FLUIDIC SILHOUETTE
OR
OUTPUT (01) IF ANY CONTROL INPUTS ARE ON
NOR
OUTPUT (02) IF ALL CONTROL INPUTS ARE OFF
AND
OUTPUT (01) IF ALL CONTROL INPUTS ARE ON
FLIP-FLOP
RETAINS OUTPUT CONDITION CORRESPONDING TO LAST INPUT
NAND
NO OUTPUT (02) IF ALL CONTROL INPUTS ARE ON
KEY
OUTPUT (01) WHEN CONTROL IS BLOCKED
BINARY COUNTER
CHANGES STATE AND RETAINS OUTPUT FOR EACH INPUT PULSE
EXCLUSIVE OR
OUTPUT (01) IF EITHER CONTROL IS ON BUT NOT BOTH

Fig.11 (right): various fluidic logic (digital) device schematics showing the valve, logical and electrical equivalents for each, as used in fluidic digital logic modules from the 1960s and 1970s by Bowles Fluidics Corporation. These were used in industrial assembly lines and by the US Navy for boiler control. *Source: Bowles Fluidics Corporation, now known as dlhBowles.*

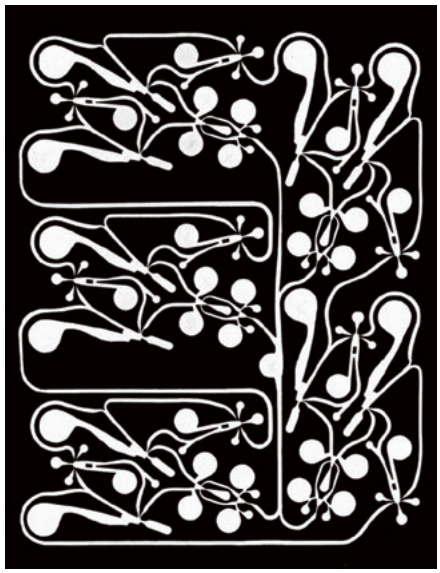


Fig.12: the channel pattern for a divide-by-ten fluidic computer component, as featured in Scientific American, December 1964. It produces one output pulse for every ten input pulses. The circuit contains ten logic elements arranged in pairs, with two on the right and three on the left. Each element has an input stream (sausage shape), an output (a small circle attached to a short, straight channel), four control jets (tear-drop shapes) and four vents (large circles).

With no flow to the control ports, the supply port provides an equal flow to both output ports, but with a flow from one control port, it produces a proportional difference in the flow to the output ports – see Fig.8.

A wall attachment fluidic amplifier, like the jet deflection amplifier, has a supply port, control ports, output ports and vents but is a digital, bistable device.

When a control port stream impinges on the supply stream, the stream remains directed to one of the output ports, even if the control port is switched off.

Fig.13: the fluidic oscillator based temperature sensor mounted on top of the vertical fin of an X-15 hypersonic aircraft.

That's because the stream is attached to one of the device's walls due to the Coandă effect (Fig.9).

Fig.10 shows how a microfluidic diode is formed, while Fig.11 gives various examples of different digital logic circuits implemented using fluidics.

Fig.12 shows a fluidic divide-by-10 counter implemented as a single, complex channel in a solid block of material. The result is quite aesthetically pleasing.

Fluidic oscillators

A fluidic oscillator is another important type of fluidic device. Fluidic oscillator temperature sensing devices were used on the X-15 rocket-powered research aircraft, as they can cope with the extremely high temperatures experienced during flight at speeds up to Mach 6.7 (7,274km/h) – see Fig.13. This was beyond the capability of resistance thermometers and shielded thermocouples.

A fluidic oscillator temperature sensor works by supplying fluid with a varying pressure of fixed amplitude and frequency to a sensor tube.

Temperature changes in this tube cause a varying phase shift in the pressure wave passing through this tube, and a fluidic phase discriminator measures the resulting phase shift and produces a signal proportional to the sensor tube temperature.

Fluidic flight controls

The BAE Systems "Demon" is an experimental unmanned aerial vehicle (UAV) with a wingspan of 2.5m, first flown in 2010. It uses fluidic flight controls, based on surface interaction and the Coandă effect, instead of conventional thrust-vectoring and flaps such as elevators and ailerons – see Figs.14, 15 & 16.

In addition to the fluidic controls, it also has conventional flaps that are presumably used as a backup system, as they are not necessary for flight control.

The elimination of flaps and conventional thrust vectoring results in much less mechanical complexity and hence greater reliability, and probably lower cost too.

The absence of moveable control surfaces on aircraft with fluidic controls also enables the aircraft shape to be optimised for a lower radar signature, and therefore improved stealth capabilities.

See the video titled *"Cranfield/BAE Systems Demon UAV's flapless flight"* at: **siliconchip.com.au/link/aarr**

Australian innovation

Australian inventor Dr Duncan

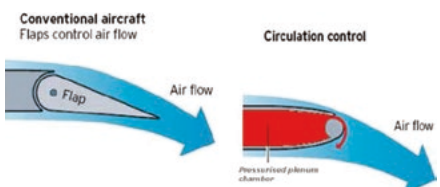


Fig.14: a comparison of airflow control on an aircraft with conventional flaps and one with fluidic control. The airflow is deflected the same in both but with fluidic control, this is done by the injection of additional air into the top of the trailing edge, which tends to follow the profile of that curved surface (due to the Coandă effect), causing deflection of the main air flow. *Source: FLAVIIR project.*

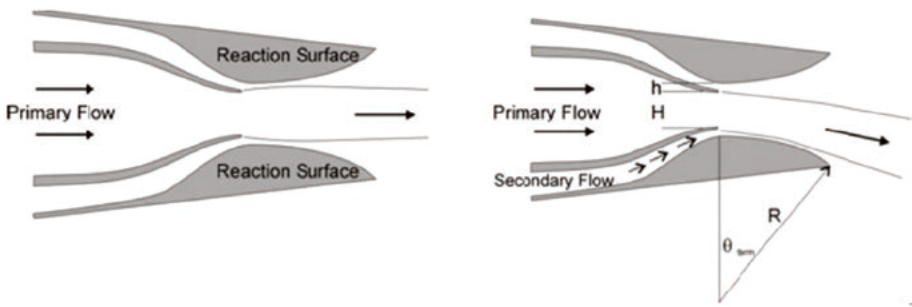


Fig.15: this shows how fluidic thrust vectoring works. There is a primary flow from the jet exhaust, as with a conventional arrangement, but then there is an additional secondary flow. Depending upon the location of the secondary flow, it causes the primary flow to be deflected up, down or sideways. *Source: FLAVIIR project.*

Fluid "Transistor" Circuits May Rival Electronics

Here's the complete story on amplifiers that use liquids or gases instead of electricity. They may soon control such things as dishwashers, power tools and computers

By S. DAVID PURSGLOVE

INSTEAD of vacuum tubes and transistors, the basic units of tomorrow's automatic appliances and automated industries might well be small blocks of metal, plastic or ceramics with tiny passageways in them.

Development of the blocks—pure fluid amplifiers—was announced recently by the Army's Diamond Ordnance Fuze Lab., Washington, D. C.

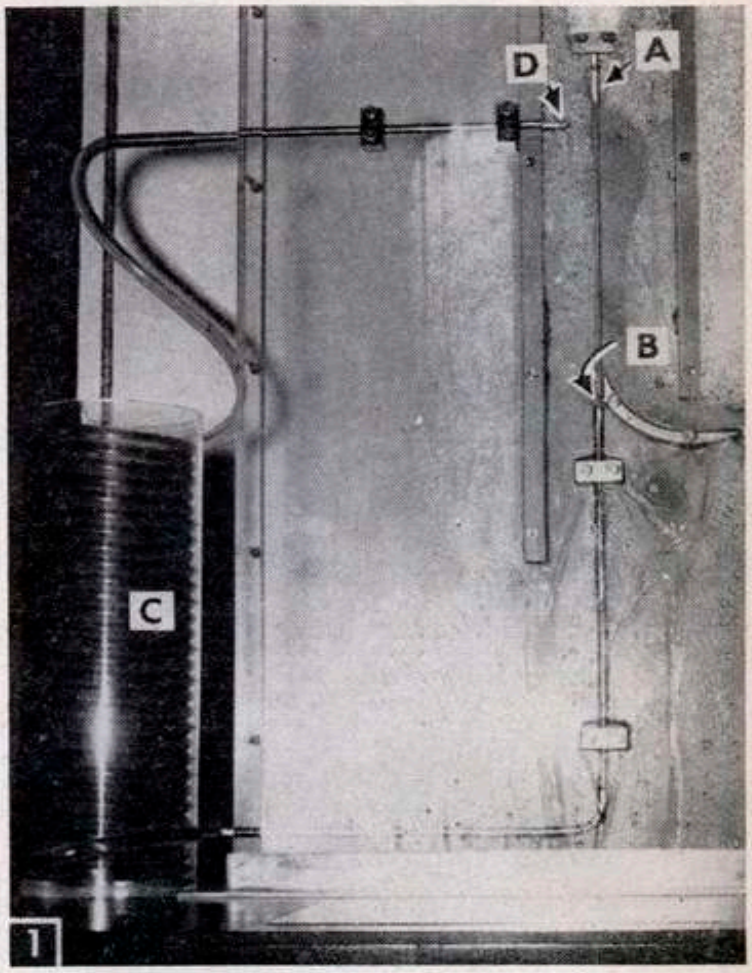
Their inventors believe the blocks are the basis for an entirely new industry which could rival electronics within 10 years. Pure fluid amplifier (PFA) circuits can be used to do almost anything electronic circuits can do: Amplify, compute, reason, remember, control and direct.

They can control power tools, computers, chemical processes, home dishwashers, windshield wipers, speedboat hydrofoils and all kinds of motors and engines.

Besides their uses in industry—where they can simplify machines and processes and eliminate many moving parts—PFA's will also be important to home experimenters.

Almost everything that has been done so far in the Army laboratory can be done in the home workshop. Tool and model makers at Diamond Ordnance Fuze Laboratory have made basic pneumatic control units from paraffin, modeling clay, soap and wood to allow experimentation and modification before making the same units from more permanent materials.

How PFA Works. Basically, pure fluid amplification is the control of a high powered



This simple device—nothing more than some tubing connected to a water supply—is an oscillator that uses water instead of electricity. (A) is control stream opening; (B) is feedback collector; (C) is feedback coil; (D) is control jet. Operation of oscillator is explained on p. 82.

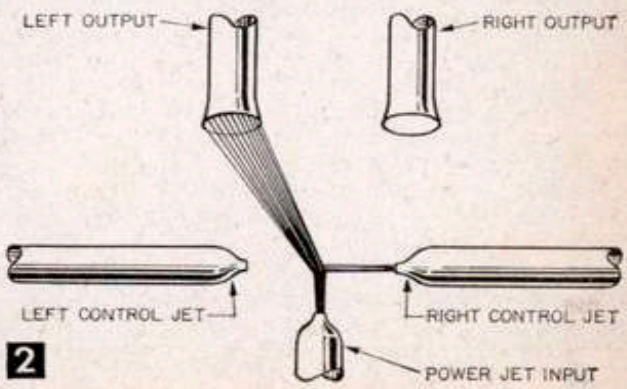


Diagram shows deflection of a power stream by a control stream—a basic amplification function. Without control jet, power stream would merely shoot between outputs. Use of left jet would send it into right output.

One of the first mentions of fluidics or pure fluid amplifier circuits (PFAs, as they were then known) from Science and Mechanics magazine of June 1960. This was the first page of the article. It notes that "Almost everything that has been done so far in the Army laboratory can be done in the home workshop".

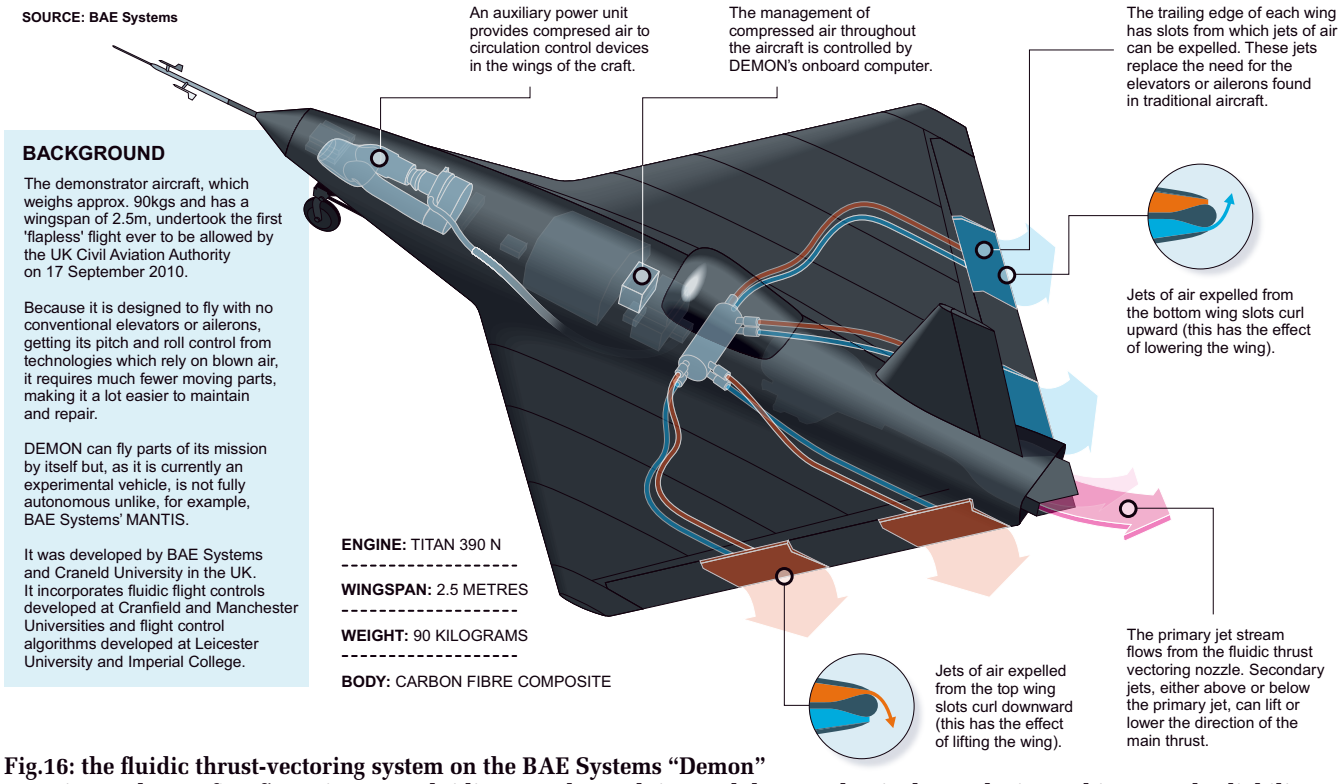

SOURCE: BAE Systems
BACKGROUND
The demonstrator aircraft, which weighs approx. 90kgs and has a wingspan of 2.5m, undertook the first 'flapless' flight ever to be allowed by the UK Civil Aviation Authority on 17 September 2010.
Because it is designed to fly with no conventional elevators or ailerons, getting its pitch and roll control from technologies which rely on blown air, it requires much fewer moving parts, making it a lot easier to maintain and repair.
DEMON can fly parts of its mission by itself but, as it is currently an experimental vehicle, is not fully autonomous unlike, for example, BAE Systems' MANTIS.
It was developed by BAE Systems and Craneld University in the UK. It incorporates fluidic flight controls developed at Cranfield and Manchester Universities and flight control algorithms developed at Leicester University and Imperial College.
ENGINE: TITAN 390 N
WINGSPAN: 2.5 METRES
WEIGHT: 90 KILOGRAMS
BODY: CARBON FIBRE COMPOSITE
An auxiliary power unit provides compresed air to circulation control devices in the wings of the craft.
The management of compressed air throughout the aircraft is controlled by DEMON's onboard computer.
The trailing edge of each wing has slots from which jets of air can be expelled. These jets replace the need for the elevators or ailerons found in traditional aircraft.
Jets of air expelled from the bottom wing slots curl upward (this has the effect of lowering the wing).
The primary jet stream flows from the fluidic thrust vectoring nozzle. Secondary jets, either above or below the primary jet, can lift or lower the direction of the main thrust.
Jets of air expelled from the top wing slots curl downward (this has the effect of lifting the wing).

Fig.16: the fluidic thrust-vectoring system on the BAE Systems "Demon" experimental UAV, first flown in 2010. Fluidic controls result in much less mechanical complexity and improved reliability as well as better stealth (low radar signature), as the shape of the aircraft can be optimised without moveable flaps. The primary thrust (jet exhaust) is vectored by fluidic control; conventional trailing-edge wing flaps are also replaced by fluidic controls.

Campbell invented an anaesthetic machine in 1973 that employed fluidic controls, including the Coandă effect.

This machine became extremely popular in Australia and New Zealand.

Vortex flow-based fluidics

As mentioned earlier, fluidic devices based on vortex flow include certain shower heads, windscreen washer nozzles, flow rate meters and a switching device to alternately fill and empty bladders in a massage chair (Fig.17).

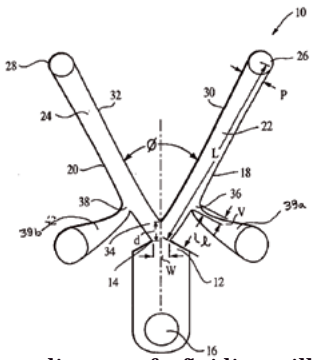


Fig.17: a diagram of a fluidic oscillator with no moving parts from US patent 6,916,300 for a seat massager from dlhBOWLES, Inc. An air source is supplied at the bottom (16) and is alternately directed to the supply lines to bladders in the chair connected to 26 and 28. The air from the bladders is alternately vented at vents 39a and 39b.

A windscreen washer nozzle may seem a humble application for fluidics, but such a nozzle containing a fluidic oscillator (like some shower heads – see Fig.18) has the capability of sweeping up and down and from side to side with no moving parts (see Figs.19, 20 & 21).

The leader in this field is dlhBOWLES (https://dlhbowles.com/). They report the following benefits from their nozzle:

* Cleans 62-70% faster
* Uses 65-74% less fluid to clean
* Allows for 53-65 more cleanings per bottle fill
* Pre-wets an area 19-23 times larger
* Holds spray position better at all road speeds
* Greatly improved visibility and driver safety
* Dramatically reduced smearing, streaking
* Significantly reduces wiper blade wear

For more information, see the video titled *"FLUIDICS - FULL SPEED, FLUENT VIEW & SLOW MOTION"* at: siliconchip.com.au/link/aars

There is no mention of which cars use these nozzles, but one web reference states that Nissan vehicles have

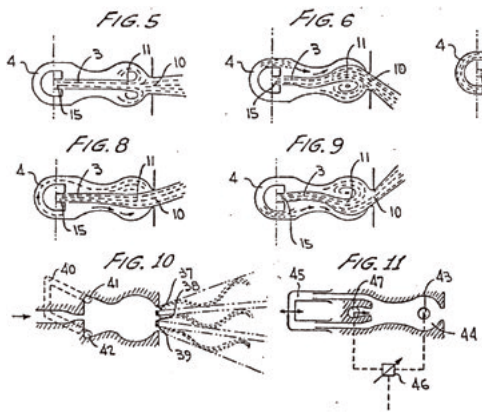


Fig.18 (left): diagram from 1989 European Patent EP0319594A1 for a "Fluidic oscillator with resonant inertance and dynamic compliance circuit". This can be used in a pulsating shower head or other pulsating water jet device, and has no moving parts. Sub-figs.5-9 show the flow pattern in the device while Sub-fig.10 shows the pattern of jets from such a device with multiple outlets. Sub-fig.11 shows a means to adjust the device.

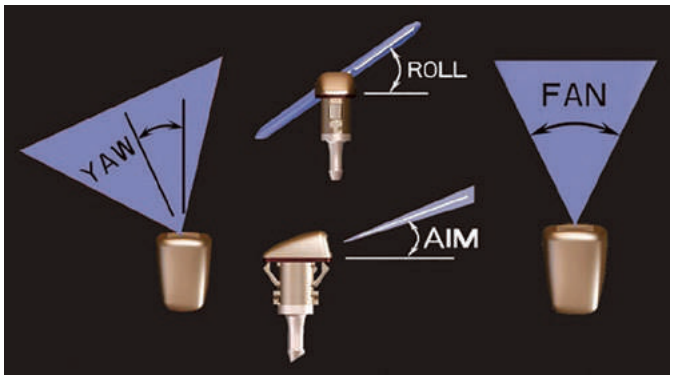


Fig.19: a fluidic windscreen spray nozzle from Bowles Fluidics Corporation illustrating different oscillatory spray motions, all achieved without moving parts.

had them since 2004 and they are also available as aftermarket accessories for certain cars.

dlhBOWLES makes over 40 million fluidic oscillator spray nozzles per year, of various types and has over 230 patents in the area. The same company makes the fluidic oscillator for a massage chair that alternately fills and empties two bladders mentioned earlier (Fig.17).

Fluidic flow measurement

Sontex (**https://sontex.ch/en/**) have a range of meters to measure flow rates of fluid in heating systems. They utilise a fluidic oscillator which has a frequency dependant upon its flow rate. A piezoelectric sensor measures the frequency of oscillation in the fluidic oscillator, and thus the flow rate is determined with no moving parts – see Figs.22 & 23.

See also the video titled *"Sontex Superstatic 749 Fluidic Oscillator Heat Meter"* at: **siliconchip.com.au/link/aart**

Fluidic computers

MONIAC (Monetary National Income Analog Computer) was also known as the Phillips Hydraulic Computer and the Financephalograph.

It was invented by New Zealander Bill Phillips in 1949 and is generally regarded as a fluidic computer.

It is a water-based computer that uses fluidic logic and was initially designed as an educational tool, but was found to be a useful economic modelling device as digital computers at that time were not widely available. It was also used for military purposes.

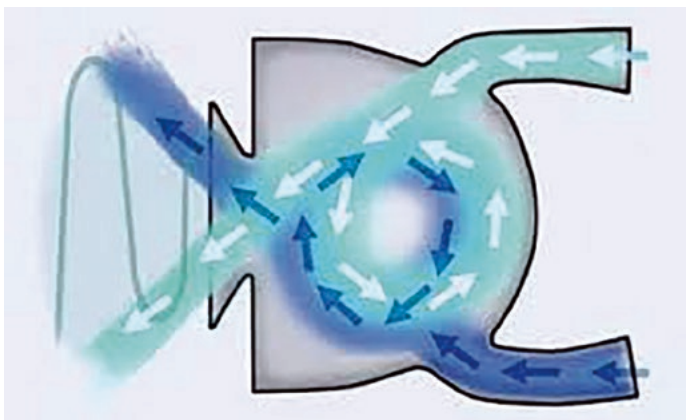


Fig.21: the flow pattern inside a fluidic cleaning nozzle from automotive technology company Continental (siliconchip.com.au/link/aaru), which manufactures fluidic nozzles to clean automotive headlights, cameras and LIDAR sensors.

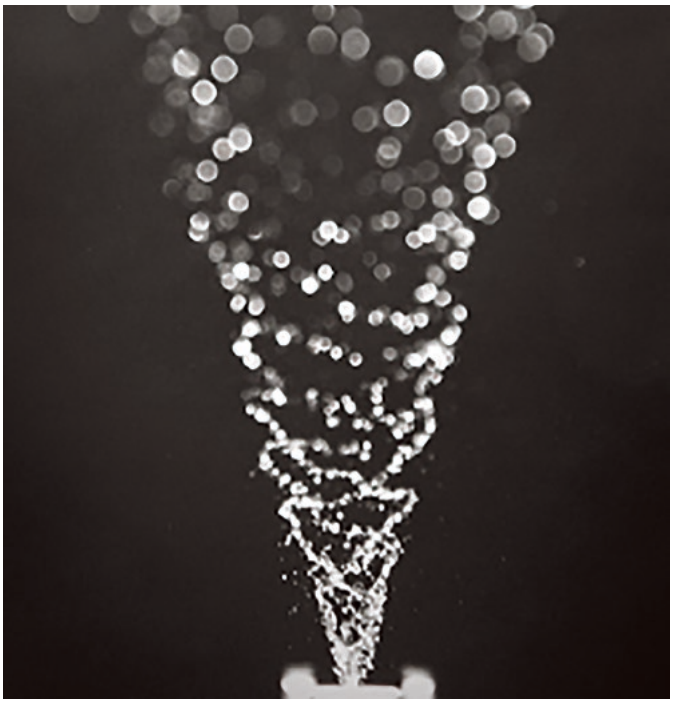


Fig.20: the spray pattern from the Bowles fluidic windscreen washer nozzle. A conventional nozzle would produce a single stream of fluid.

Twelve to fourteen of these machines were built, and there is a working one on display at the Reserve Bank of New Zealand and another at Cambridge University in the UK (see Fig.26). There is also a non-working one on display at the University of Melbourne.

Various economic parameters such as the amount of money in the treasury, health and education expenditure, taxation and tax rates, savings, investment income, import expenditure and export income could be input via valve adjustments, and accumulated funds were represented by the amount of fluid within tanks.

Results could be recorded on a mechanical plotter. While MONIAC is generally regarded as a fluidic device, it did have some mechanical components, so it was not a fluidic device in the purest interpretation of the term, but a hybrid system.

See the videos titled *"Making Money Flow: The MONIAC"* (**siliconchip.com.au/link/aarv**), *"Moniac Economic Analog Computer"* (**siliconchip.com.au/link/aask**) *and "Matletik*

Fig.22: the Sontex Superstatic 749 flow rate meter, utilising fluidic oscillation and a piezoelectric sensor for reliable measurement without moving parts.

Table 1:
1972 NASA list of fluidic systems in commercial use

- Automatic turret lathe sequencing
- Automatic sealing of random-sized boxes
- Measurement and control of frost buildup on refrigerator coils
- Punch press work positioning
- Photographic film winding control
- Gauging for automatic grinding machines
- Candy box filling machine control
- Scale control for weighing explosives
- Sewing machine trimming knife actuation
- Controlling a semiautomatic crimping machine
- Controlling paper making machinery
- Automatic punching machine operation
- Sewage pumping station liquid level control
- Soft drink bottle casing
- Thread, wire, or rod diameter measurement
- Bow thruster for boat or ship
- Breathing assist device
- Automatic boiler control
- Non-contact position measurement or proximity switching
- Counter systems (predetermining and cumulative)
- Disk memories for computers
- Automated paint spraying
- Alphanumeric displays
- Leak testing of automobile gasoline tanks
- Pallet loading of different size boxes and conveyor control
- Newspaper materials handling machine controls
- Ordnance round assembly tolerance inspection
- Machining and assembly control of live mortar rounds
- Inspection/classification of automotive pollution control valves
- Liquid drum filling monitoring and control
- Scrap metal baler control
- Metal tapping machine control
- Steam turbine governor
- Gas turbine or jet engine overspeed limiter
- Broken tool detector
- Moving belt edge guide control
- Bin level control for liquid, powder, and small parts
- Environmental control in large buildings
- Industrial air motor governors
- Life test cycling of heart pump check valves
- Automatic cold saw cutting-angle setting
- Monitoring and control of vacuum in tyre making equipment
- Filter bag cleaning controls in tyre making equipment
- Paper splice detection for paper coating machinery
- Lip-seal inspection using moving-part logic
- Life test cycling of postage meters
- Coil winding machinery controls
- Acid vaporiser controls for textile processing
- Irrigation channel switching
- Fluidic lawn sprinklers
- Tachometers for diesel motor ships
- Transistor lead bender

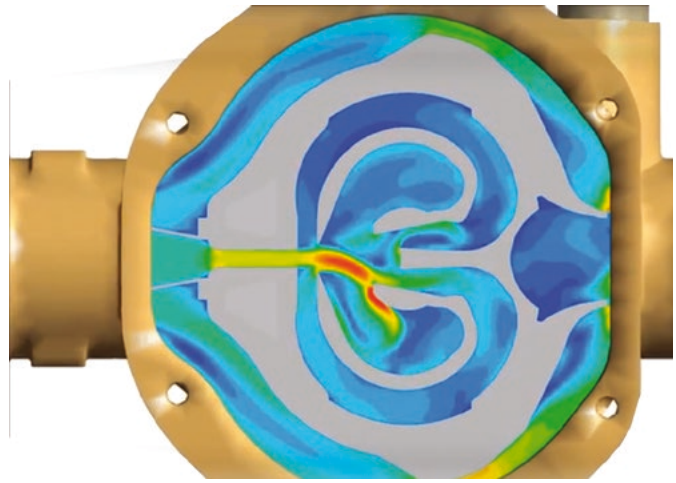


Fig.23: a video screen grab of a Sontex meter showing details of its fluidic oscillator, with simulated fluid flow via computational fluid dynamics. The stream switches between the two lobes seen in the centre and the frequency at which this happens is proportional to the flow rate.

Moniac Simulation" (siliconchip.com.au/link/aarw).

You can experiment with a virtual MONIAC at: siliconchip.com.au/link/aarx (note: the Flash plug-in is required in your web browser).

Another simulator is available at the AnyLogic Cloud at the following link, which does not require Adobe Flash: siliconchip.com.au/link/aary

Microfluidics

Microfluidics takes the earlier work on fluidics and dramatically reduces the scale, operating at sub-millimetre sizes. It introduces a whole new range of possibilities, not only because of the reduced scale, but because fluids behave differently at micro scales than they do at macro scales.

To be considered microfluidics, at least one dimension of the fluid has to be in the micron or tens of microns range (one micron is one-thousandth of a millimetre).

A microfluidic device might be in the form of a 'chip', or it might utilise a microfluidic effect in another type of device such as the Australian Vortex Fluidics Device, discussed later.

At the tiny dimensions used in microfluidics, several different fluid behaviours are introduced which can be utilised in these devices. One is that the flow of fluids is no longer typically turbulent but rather, laminar (see Fig.24) and therefore fluids do not flow or mix with other fluids in the traditional sense.

This "clean" flow allows for precise control of fluids such as their movement and their mixing (or not mixing). For example, two streams of different fluid can exist side-by-side, or a bubble of one type of fluid can exist inside a medium of a different type.

Books on fluidics

Today, there is not much readily available information on fluidics, but two books of interest are "*Fluid Logic Controls and Industrial Automation*" by D. Bouteille (Wiley, 1973) and *"Fluidics: Components and circuits"* by K. Foster and G.A. Parker (Wiley-Interscience, 1970).

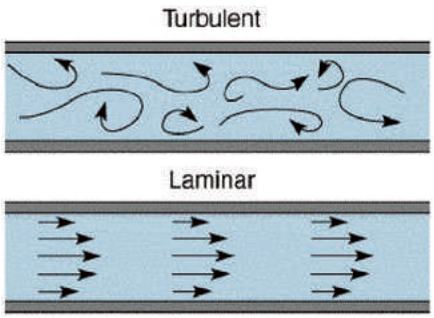


Fig.24: turbulent and laminar flow. Laminar flow is what almost always occurs in microfluidic devices.

Microfluidic chip devices are often made from glass, silicon or a silicone polymer or other diverse materials, with channels etched or moulded into the device. "Inputs" and "outputs" from the device to the outside world are made with fine tubes; for example. a syringe needle can be used in prototypes.

A typical experimental device might consist of something like a glass microscope slide as a base with a silicone polymer on top that has the channels moulded into it.

Photolithography can be used to produce the desired pattern, similarly to how conventional microchips are made. See Fig.25 for details of the basic fabrication process.

Fluids are pumped from the external environment into the microfluidic device, where they undergo the desired process(es) and are then removed from the device.

The processes undertaken might include mixing, sorting, or a chemical or biochemical reaction.

Apart from actions caused by the mixing and arrangement of channels in the device, materials used in the device's fabrication may be chemically or biochemically reactive and participate in the desired reaction within the device.

So-called 'droplet fluidics', with a bubble of one type of fluid inside a different media is becoming an important part of microfluidics for performing or controlling certain types of chemical or biochemical reactions (see Figs.27-30).

Once droplets are formed, they can be collected and used, or two different types of droplets can be merged for effective mixing (not possible at a larger scale).

Individual droplets can also be sorted or separated according to some pa-

Fig.25 (right): the fabrication of a basic microfluidic device. First, a 'master' is made using photolithography with the inverse of the desired shape, then the silicone polymer (PDMS plastic) is poured onto this and cured. This is then peeled from the master and it is attached to a glass substrate, and access ports added. *Source: A. San-Miguel & H. Lu, Creative Commons Attribution-Share Alike 3.0 Unported license.*

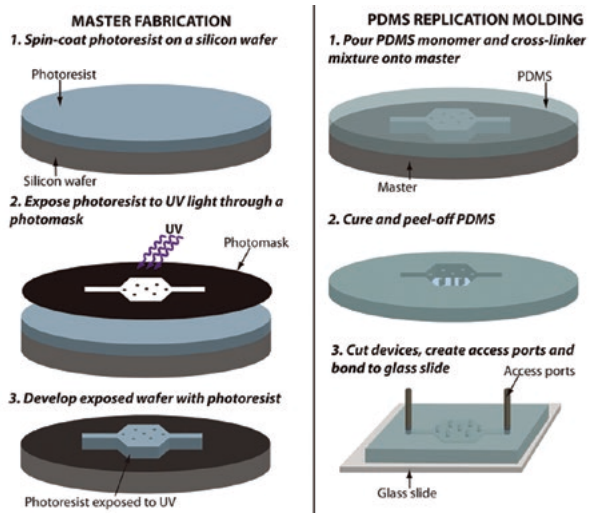
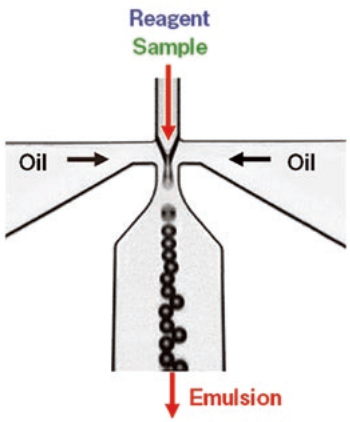


Fig.26: a MONIAC fluidic logic computer at the Science Museum, London. *Credit: Wikimedia user Kulmalukko (Creative Commons Attribution-Share Alike 3.0 Unported license).*



Emulsion generation process within a microfluidic chip

Fig.27: a microfluidic chip scheme to generate droplets, a common operation. In this case, a reagent is injected from the top and oil is injected from the sides to generate an emulsion of reagent droplets within oil. Note how the reagent stream is 'pinched' and broken off as it goes through the restriction. This is called "flow focusing". The width of the reagent channel might be 20 microns or so, and the emulsion containing channel might be 100 microns (0.1mm). *Source: On-Chip Biotechnologies Co Ltd, Japan.*

rameter such as colour. Another thing that can be done with droplets is to put individual biological cells inside them.

There are numerous applications for microfluidics, such as biological cell sorting (Fig.30), digital microfluidics to move droplets around on a chip such as the OpenDrop (Fig.32) or microfluidic transistors (Fig.33) and a soft robot-like "Octobot" that uses a microfluidic logic controller (Fig.34) – see the video titled *"Octobot: A Soft, Autonomous Robot"* at: siliconchip.com.au/link/aarz

Other biological uses for microfluidics include creating artificial lungs (as shown on page 15) and testing liver function.

There are even microfluidic devices printed on paper with the help of a specialised inkjet printer and others too numerous to detail here, beyond these few

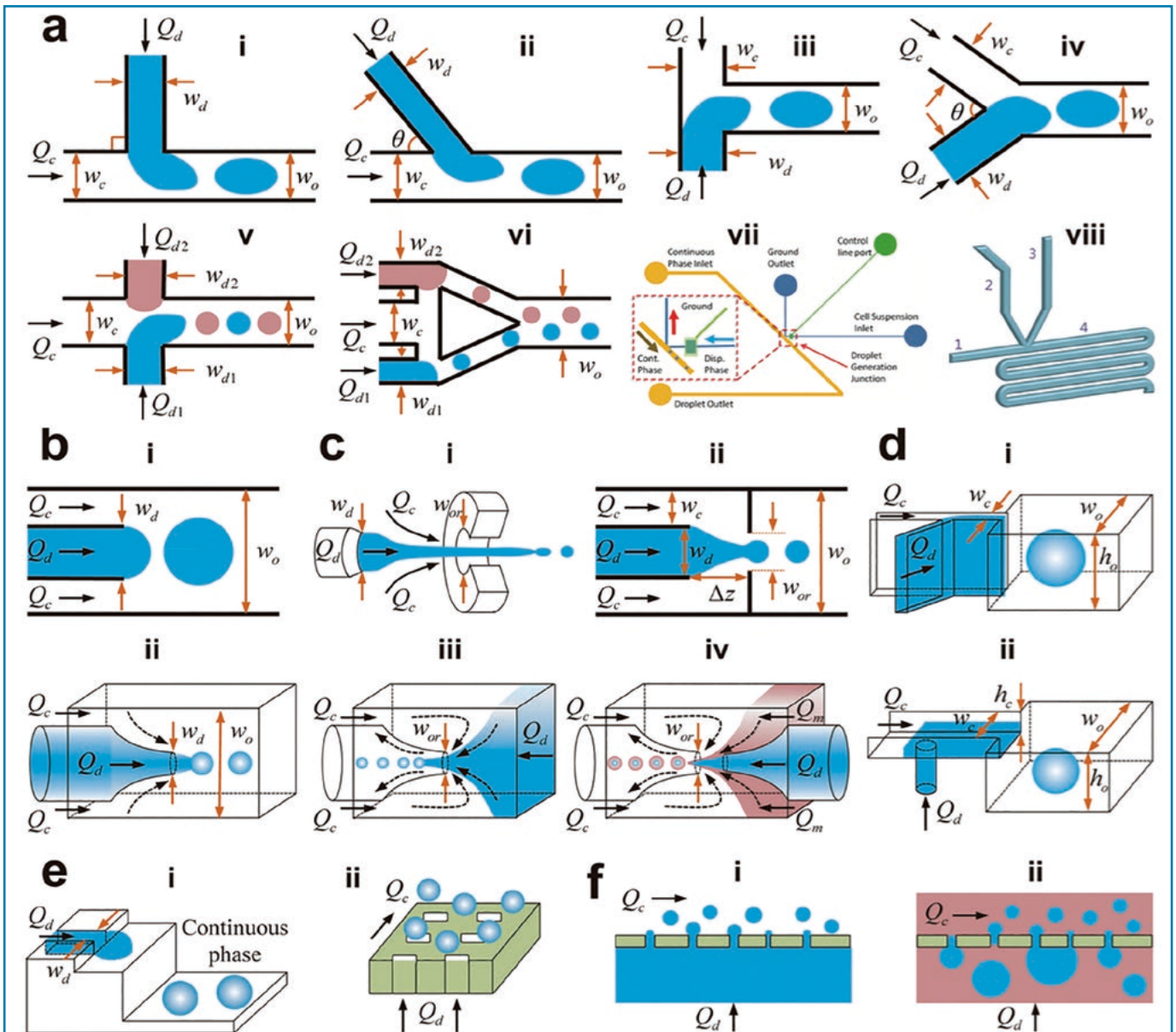


Fig.28: a variety of methods of microfluidic droplet formation, as used in "droplet fluidics" mentioned in the text: a) cross-flow, b) co-flow, c) flow-focusing, d) step emulsification, e) microchannel emulsification; and f) membrane emulsification. The coloured fluid patterns reveal the process of droplet formation. *Source: P. Zhu & L. Wang, Creative Commons Attribution-ShareAlike 3.0 Unported license.*

Fluidics projects that you can try at home

You can make a computer similar to the MONIAC fluidic computer described in the main text using drinking straws, water bottles and some other pieces. See the video titled *"A 3-bit hydro-pneumatic"* at siliconchip.com.au/link/aas0

Author "dAcid" has described pneumatic logic gates made with simple tools on the Instructables website, at: siliconchip.com.au/link/aas1 (see Fig.a).

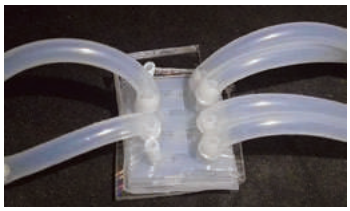


Fig.a: a simple pneumatic logic gate, as described by author "dAcid".

Note that CNC equipment is required for this. You might be able to get access to such equipment at your local Makerspace if you don't have any. Google the terms "makerspace" and the name of your town or city and find one that has appropriate equipment.

Author "novelchip" on Instructables has described vacuum-powered fluidic ink "LEDs" and circuits at: http://siliconchip.com.au/link/aas2 (see Figs.b, c & d).

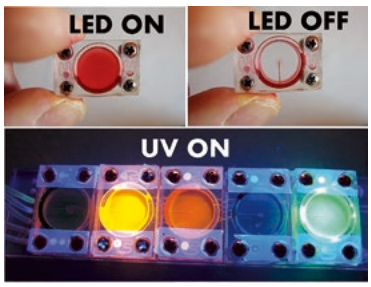


Fig.b: "LED" indicator devices implemented using fluidics. The devices on the bottom row fluoresce under UV light.

Also see the videos at: siliconchip.com.au/link/aas3 and siliconchip.com.au/link/aas4

Once again, note that CNC equipment is required to make these devices.

OpenDrop (siliconchip.com.au/link/aas5) is an open-source hardware and software project that is a "desktop digital biology laboratory".

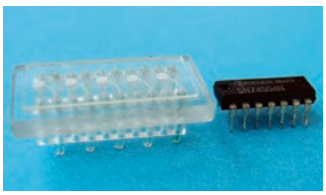


Fig.c: a fluidic integrated circuit (a hex inverter) by author "novelchip", alongside its electronic equivalent, the Texas Instruments SN74S04N. In this case, the fluidic version is not much bigger than the electronic one.

Quoting directly from their website, "OpenDrop is a new design for an open source digital microfluidics platform for research purposes. The device uses modern electro-wetting technology to control small droplets of liquids."

"Potential applications are lab on a chip devices for automating processes of digital biology. However, the present design should also open the technology to other field and allow experimentation to find new applications. Including the field of art, music, games and education."

Liquid droplets are moved around the device under an electric field of up to 300V AC or DC.

For some current OpenDrop projects, see: siliconchip.com.au/link/aas6

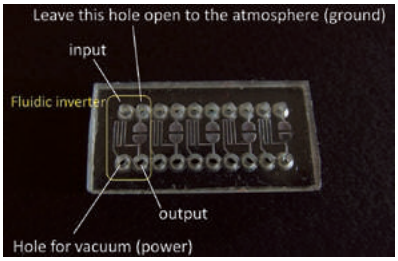


Fig.d: details of the fluidic hex inverter integrated circuit shown in Fig.42, taken from the Instructables web page.

For videos about how liquid drops are manipulated in the device, see the video titled *"OpenDrop Liquid Reservoirs"* at: siliconchip.com.au/link/aas7 and *"Control Software for OpenDrop V3 Digital Microfluidics Platform"* at: siliconchip.com.au/link/aas8

There is a Russian YouTube video titled *"Binary pneumatic adder from paper"* at: siliconchip.com.au/link/aas9 and an associated description in Russian, at: siliconchip.com.au/link/aasa by author Aliaksei Zholner (see fig.e).

You can use Google to translate the text into English. The logic devices are made from paper, so no special equipment whatsoever is needed (except a stream of air; the author uses a balloon). The author does not use the term "fluidic", although that is the operating principle of the constructed devices. Logic elements AND, OR, XOR gates and a transistor are made. It is a very clever digital fluidic computer.

If you have a 3D printer, you can go to www.thingiverse.com and search using the term "fluidic" to find some fluidic devices you can print.

There is a good discussion of some of the challenges in making a home-built fluidic computer at: siliconchip.com.au/link/aasb but there is no indication as to whether the author ever built this computer. There are some interesting ideas there if you want to build your own!

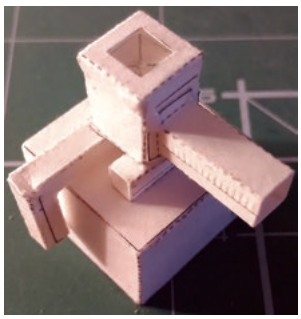


Fig.e: an element of the paper-based fluidic computer.

One of many companies selling microfluidics components is the microfluidic ChipShop (siliconchip.com.au/link/aasc), although there are others. Fig.f shows some of the materials available for experimenters.

Fig.f: a microfluidics starter kit from the microfluidic ChipShop that comes with a frame to hold chips, connectors, two straight channel chips with four channels (200 microns square), two straight channel chips with four channels (100 microns square), one straight channel chip with 16 channels (1000 x 200 microns), H-shaped channel chip, droplet generator chip, PCR (polymerase chain reaction) chips and 120 microlitre rhombic chamber chip.

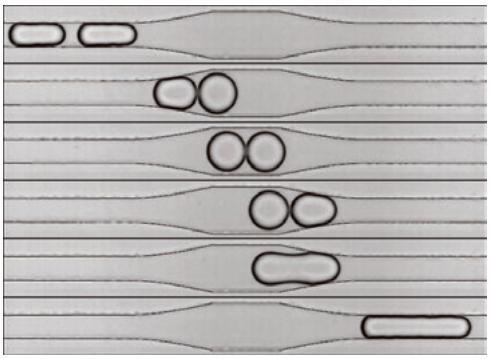


Fig.29: one possible microfluidic scheme for merging two droplets. The direction of motion is left to right and top to bottom.

representative examples.

More Australian innovation

A fluidic device has been invented by researchers at Flinders University in South Australia, in the University's Institute for Nanoscale Science and Technology.

It is called the Vortex Fluidics Device or VFD. The VFD works by delivering reagents to a rapidly rotating tube in which a thin (250 micron or 0.25mm thick) film is produced, which results in intense mixing.

Demonstrated applications include protein folding and unfolding. Famously, it was used to "unboil an egg" (see siliconchip.com.au/link/aasd).

It can also be used for biodiesel production at room temperature without solvents; pharmaceutical synthesis with continuous flow and high yield; mesoporous silica production at room temperature; plasma processing with a plasma in contact with a thin film; and various applications in synthetic organic chemistry, including making the anaesthetic lidocaine with much less waste than normal, plus many other applications.

The technology has already been commercialised. Flinders Partners, the commercial arm for Flinders University, launched Vortex Fluidic Technologies (siliconchip.com.au/link/aase) in July 2015, to help commercialise the VFD.

2D Fluidics Pty Ltd (www.2dfluidics.com) was formed in 2018 through a collaboration between ASX-listed First Graphene Ltd and Flinders University.

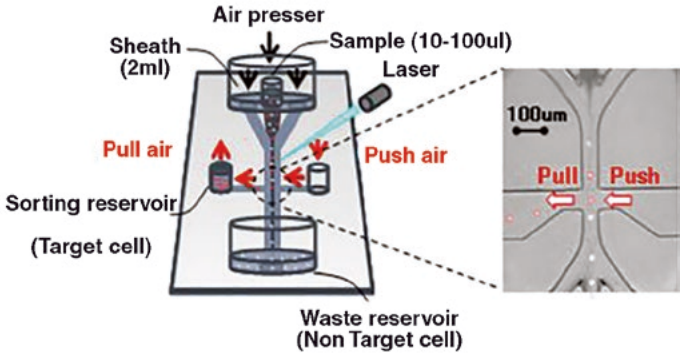


Fig.30: microfluidics biological cell sorting. The cells are probed with a laser and those determined to be separated are pushed into a reservoir. *Source: On-Chip Biotechnologies Co Ltd, Japan.*

2D Fluidics produces electronics-grade graphene and specific length carbon nanotubes without harsh or toxic chemicals, for research and commercial purposes, plus sells VFD devices.

For videos about the VFD, see:

* *"Introducing the Vortex Fluidic Device"* at: siliconchip.com.au/link/aasf
* *"Fluid Dynamics Within the Vortex Fluidic Device"* at: siliconchip.com.au/link/aasg
* *"Droplet Dynamics Within the Vortex Fluidic Device"* at: siliconchip.com.au/link/aash
* *"ABC News 24 - Ig Nobel prize winner Raston cracks global anaesthetic"* at: siliconchip.com.au/link/aasi

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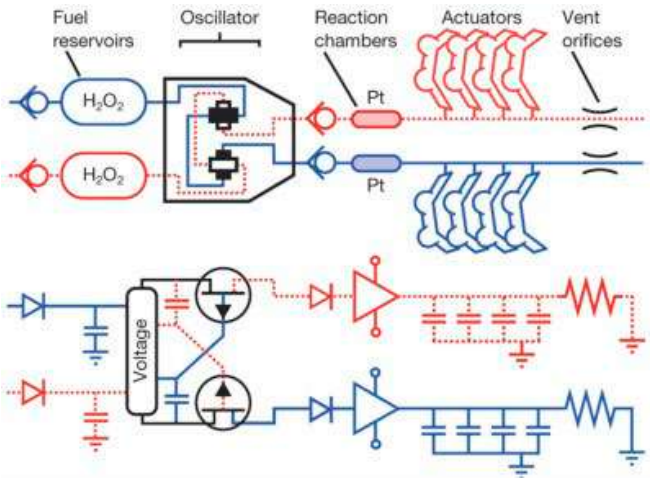


Fig.32: a microfluidic logic and motor circuit (top) along with the electronic equivalent (bottom) for Octobot. This is said to be the world's first autonomous soft robot.

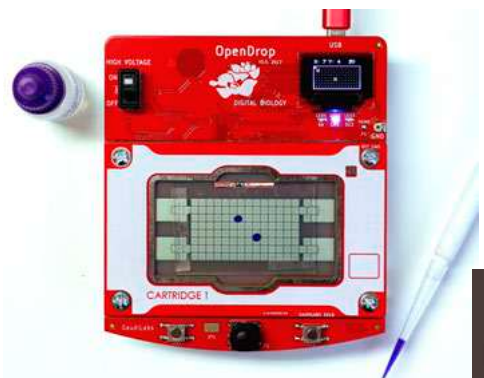


Fig.31: the OpenDrop v3 is a digital microfluidics development board, shown with a bottle of reagent and a micropipette. This is available for a base price of €695 (AU$1120) at the time of going to press. The blue liquid drops can be seen in the large gridded area, and the location for the next move (as directed by software) is shown in the OLED screen at upper right.

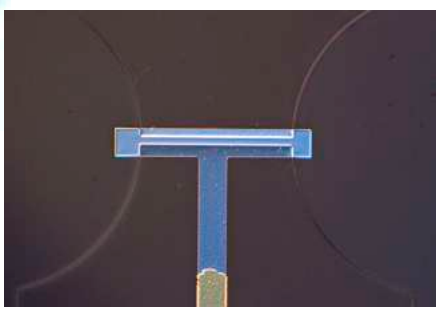


Fig.33: a microfluidic transistor, as might be used in a microfluidic logic device.

Fig.34: Wyss Institute of Harvard University's 3D printed Octobot, powered by microfluidic logic and motor.

a new concept for Australian electronics:

jaycar maker hub

The maker movement is a world-wide phenomenon, credited with introducing countless thousands (millions?) to electronics. Jaycar's latest store at Central Park in Sydney is dedicated to makers at all levels.

Inside their new Central Park Mall store on Broadway, Jaycar Electronics has something quite different: a "Maker Hub". It's not in New York, it's right here in Sydney; Broadway is one of the main thoroughfares heading south out of Sydney city and Central Park Mall is a modern mall featuring greenery both inside and out (right near Central Station, hence the name).

We toured the new store and its integral Maker Hub, and we liked what we saw.

It provides a place for Jaycar "Nerd Perks" members to work on their projects, and gives them access to some fairly advanced equipment for nominal fees.

And the fully-stocked Jaycar Electronics store means that if you need a part or tool for our project, you won't have to go very far!

If you aren't familiar with the Maker movement, refer to our article on the Sydney Mini Maker Faire in the January 2014 issue (siliconchip.com.au/Article/5688).

The store

The first thing that struck us upon seeing the store is the new styling, with plenty of open space and neatly organised products.

You might have seen some small changes at your local Jaycar or in their latest catalog, but the full extent of Jaycar's new look is visible there. In addition to the new logo and uniforms, the shop generally has a more modern and open feel.

Of course, style is not everything, especially when you are only interested in finding that one part for your next project. The aisles are wider and there is more space to move.

There's far less need to crouch down and reach into cramped spaces to find and retrieve the parts that you need.

And if you are looking at a cable, you will easily find it on the

By Tim Blythman

Even the entrance to Jaycar's new store and Maker Hub is quite different to existing stores. The Maker Hub is given its own dedicated area within the store.

Along with individual work areas, the Maker Hub features conference or seminar areas where groups can gather to hear from guest makers or just to collaborate on projects.

'Cable Wall' along one side of the shop.

The way components are displayed has been massively improved. Instead of rows of plastic tubs, most of the smaller components are now housed in so-called (according to our guide) 'turbines'. These are rotating, segmented towers which can be spun to quickly find the part you are looking for.

The Maker Hub

Perhaps most interesting is the 'Maker Hub' element of the store. It's tucked away in the back corner, but with a fantastic view of the park behind the mall. It consists of several benches, slightly higher than waist height. Maker Hub is written in giant letters on the ceiling, which can be seen from outside the building.

The Maker Hub is being used to host workshops and other events, and can also be used by Nerd Perks' members to work on their own projects. Nerd Perks is Jaycar's loyalty program.

During the time we were there, we saw a workshop in progress. One of the staff members was demonstrating how to turn a Raspberry Pi single-board computer into an arcade game (using an assortment of other Jaycar parts). The enthusiastic participants were a mix of ages and genders.

Also in evidence were several 3D printers, many of them busy turning out an assortment of small plastic widgets.

It's apparent that Jaycar Electronics is embracing 3D printing; we counted at least six different models on display. They are all available for purchase, including a tiny model for only $299.

A sign indicates that you can print your own 3D design using their printers, for 30c per gram of filament. While the cost of 3D printers has plummeted, they are still a substantial outlay, so this is both a great way to 'try before you buy', and also an excellent service for people who do too little 3D printing to justify buying their own printer.

Or you can just try it out, to see if you like it.

The Maker Hub also features an assortment of other exciting equipment that you can use. There is a 3D scanner, which can produce a 3D model of solid objects, that can then be replicated using one of the 3D printers. One of the staff members suggested that this could be used to scan broken parts to create replacements.

That is an idea which we can imagine would appeal to many people, not just those with an interest in 3D printing.

To our delight, they also have a Voltera V-One PCB printer. We briefly described this device in our July 2019 article on Making PCBs (**siliconchip.com.au/Article/11700**). A sample prototype that it had produced was on display, featuring a small PCB with an 8-pin SOIC (SMD) chip flashing several onboard LEDs.

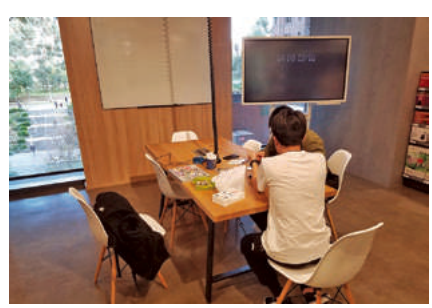
The board looked quite tidy. Like the 3D printers, it appears this unit will be available for customers to use, although the actual details of this are still to be decided. We might keep this in mind next time we need a prototype in a hurry…

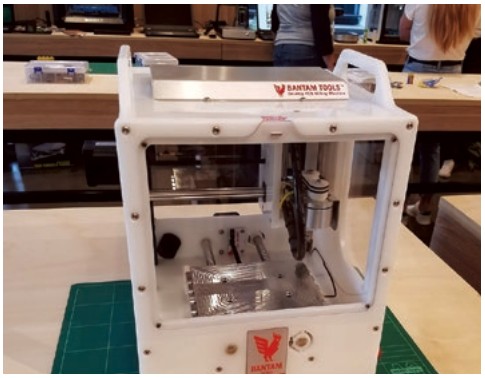
There was a Bantam PCB Milling Machine on one of the benches too; we also mentioned this in our Making PCBs article. We didn't get to see it in operation, but it is another way that Maker Hub customers can create prototype PCBs.

Jaycar will also be adding a laser cutter to the list of machines that you can 'rent'. It would have been there already except that it got stuck in customs! They will have plastic sheets available that you can use to cut out your designs, again for a nominal charge. They also suggested that customers may be able to use the laser cutter to make holes in boxes they've just purchased (eg, in the lids).

Also on display was the SnapMaker CNC machine. This is a 3-in-1 machine with interchangeable tools, including modules for 3D printing, CNC milling and laser cutting. Again, we were not able to see it in action, and we suspect that both lasers and CNC milling heads will need to be safeguarded in such an environment.

Along with the vast number of 'grown-up toys', there was a display featuring robot kits aimed at younger people, as well as a table in the Maker Hub set up to demonstrate the mBot





(Left): a Voltera V-One PCB printer, which we mentioned in last month's feature on making PCBs. At right is the Bantam Tools Desktop PCB Milling Machine. Jaycar has plans to rent these (and other) in-house machines to makers for a nominal charge.

programmable robot, including an obstacle course to be negotiated.

They also have a small meeting table next to a digital whiteboard for brainstorming, along with a regular whiteboard, for those who prefer the old-school methods.

Small groups can come up with design ideas and use the digital whiteboard to save their deliberations to a USB stick (and perhaps take a photo of the regular whiteboard to record its contents).

Jaycar's educational focus

Jaycar's STEM education (science, technology, engineering and mathematics) focus has always been strong; consider the Short Circuits project books and kits, which go back over 20 years (which, incidentally, were designed by SILICON CHIP staff).

The Short Circuits projects are still being sold, and robots like mBot are an impressive indication of what children have to learn with nowadays.

While we were impressed with the exotic gear that was on display, it was good to see that a couple of soldering irons were dotted around the benches, along with hot air rework stations and other soldering gear.

And right next to the Maker Hub area is a product display for Arduinos and other project construction essentials. Product placement is key!

According to our guide, the intention here is that the Maker Hub is not just a space to build your project, but also to be able to sit, plan and collaborate.

With Central Park Mall located directly opposite the campus of the University of Technology Sydney (and only a short walk from Sydney University), we expect that many students will make use of the space to work on their projects.

Summary

The "Maker" concept resonates with us, as SILICON CHIP has a strong focus on DIY electronics. In fact, we would say that our readers and we have been "Makers" long before the term was coined. Jaycar's Maker Hub is a new and interesting way of helping people like us to make things.

We're excited to see the Maker Hub, not just because they have some great toys, but because it will make building electronics much easier for many people, and may inspire the next generation of our readers.

This new Maker Hub is especially convenient because it's so close to both the Sydney CBD and Central station, with plenty of buses and trains meaning that it's easily accessible to millions of people.

While we have not seen a schedule, it appears that the Maker Hub will host workshops regularly. And assuming that it's popular, other new Jaycar stores will likely open with their own mini Maker Hubs inside.

Just as you need to be a Nerd Perks member to use the gear, you will also need to join this program to participate in the workshops.

Joining is free and also gives you aspects to certain product promotions and discounts.

The initial focus of these workshops appears to be on Arduino and Raspberry Pi based projects, although we expect to see 3D printing and CNC-themed events in the future.

We are considering hosting an occasional event at the Maker Hub, where you can meet our staff, ask questions and maybe even build a kit or two. If we decide to do so, we will announce it in advance in the magazine, so watch this space.

Jaycar's Broadway store is open from 10am until 8pm every day; the extended hours are also a boon for those needing parts for a last minute project, and as mentioned, it is a short walk from Sydney's main Central railway station. So you might even be able to grab something on your way to or from work. Did I mention the 24/7 Click and Collect parcel lockers?

For further information, see the following links:

www.jaycar.com.au/store/Broadway_JaycarAU
www.jaycar.com.au/nerdperks
www.jaycar.com.au/makerhub

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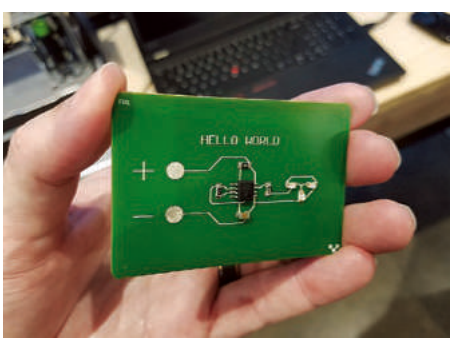
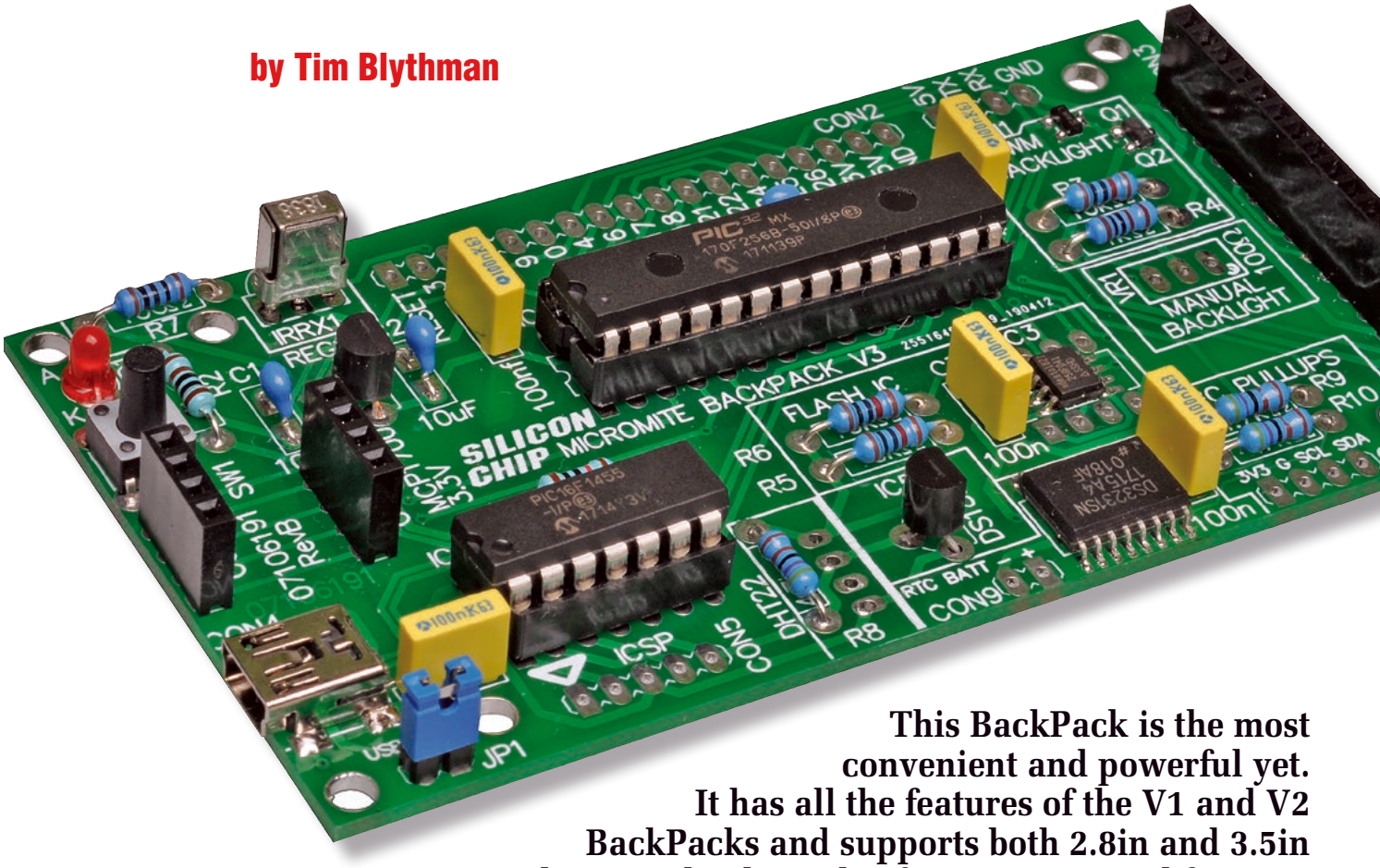


(Left): the store contains some pretty high-end gear as well, such as this Swann DVR with a number plate recognition system (want to start your own car park?). There are plans for several more 3D printers, which maker members can use for not much more than the cost of the 3D filaments. At right is a PCB "printed" by the Voltera V-One machine shown above (top left).

Micromite LCD BackPack V3

by Tim Blythman



This BackPack is the most convenient and powerful yet. It has all the features of the V1 and V2 BackPacks and supports both 2.8in and 3.5in touchscreen displays plus five new optional features which provide convenient functions. These include extra memory, temperature, humidity and pressure sensors, a real-time clock, an infrared receiver and more!

In our article on 3.5in touchscreen displays in the May 2019 issue (siliconchip.com.au/Article/11629), we looked at three different screens. But we were particularly impressed by one.

It uses an ILI9488 controller with SPI interface and has the same connections as the popular 2.8in touchscreen display used by the original and V2 BackPacks.

For that article, we supplied code to drive that new display from an Arduino and a standard Micromite. We also mentioned that we planned to write some CFUNCTIONs to speed it up, as the BASIC code is quite slow at refreshing the screen.

Not only have we now done that, but we've also designed a new version of the BackPack to properly accommodate the larger, higher resolution screen with twice as many pixels as the original (480x320 compared to 320x240).

While this article gives sufficient information for you to fully understand what we've done, if you haven't seen the V2 BackPack article in the May 2017 issue (siliconchip.com.au/Article/10652), you might want to read that one before coming back to this article.

Essentially, the BackPack is a small PCB that hosts a PIC32 running the Micromite firmware. It also provides a simple power supply, a USB interface, a header and mounting screws for a colour touchscreen and an I/O pin header.

The best part about it is that MMBasic has native touchscreen support. It's such a great idea that we've used the BackPack in numerous other projects.

But the V3 BackPack is more than just a screen upgrade.

While you can build the new V3

Features

- Compatible with Micromite LCD BackPack V1 & V2
- Suits 2.8in and 3.5in touchscreen LCD modules
- Built-in Microbridge provides serial communications and programming interface
- Mini USB socket for power and communication
- Native support for 3.5in display using initialisation CFUNCTION
- Manual or software (PWM) dimming for LCD backlight
- 4-pin I²C communication header
- Optional onboard infrared receiver
- Optional onboard DHT22 temperature and humidity sensor or DS18B20 temp sensor
- Optional onboard DS3231 real-time clock
- Optional onboard flash memory/RAM IC
- Optional onboard BME180/BME280/BMP280 temperature/pressure/altitude sensor

BackPack using the same components as the V2 BackPack, you can also add several extra components to add handy features without needing to connecting extra modules, PCBs or wiring.

You can fit it with an infrared receiver/decoder for remote control, a flash memory IC or SRAM, a DHT22 temperature and humidity sensor, a DS18B20 temperature sensor or a DS3231 real-time clock IC.

There's also a header for connecting additional I²C devices, such as a BMP180/BMP280/BME280 temperature/pressure/humidity sensor, which can be mounted directly to the board if desired.

Also, this BackPack gives you the possibility of using the SD card socket that's mounted on the back of the touchscreen board.

All the functions that were in the original and V2 BackPack are retained in the V3 BackPack, including its 50MHz 32-bit processor loaded with a powerful BASIC interpreter, which can be programmed over a virtual USB serial port.

Circuit description

We'll start by describing the core functions, which are carried over from the V2 BackPack.

Refer to Fig.1, the circuit diagram. IC1 is the main processor which runs the MMBasic interpreter and handles other functions. It is a PIC32MX170F256B (or the 50MHz variant, which is what we supply) in a 28-pin dual inline package. It requires some bypass capacitors for normal operation: two 100nF MKT capacitors across its supply rails and a 10µF ceramic capacitor to filter its internal core supply.

There's also a 10kΩ resistor used as a pull-up on IC1's RESET line, to prevent spurious resets.

IC2 is a Microchip PIC16F1455 microcontroller which is both a USB/serial converter and a PIC32 programmer – the Microbridge article in the May 2017 issue (siliconchip.com.au/Article/10648) describes its functions in more detail.

When running as a USB/serial converter, pin 5 on the PIC16F1455 receives data (ie, data from the Micromite to the PC USB interface) and pin 6 transmits data (from the PC USB interface to the Micromite).

These signals also run to the edge pins for the console connection (CON1) in case you build this PCB but for some reason do not plug the Microbridge IC, IC2, into its socket. In this case, you can use an external USB/serial converter.

The PIC32 programming interface from the Microbridge is on pins 7, 2

and 3 of IC2. These provide the reset function, program data and clock signals, which connect to pins 1, 4 & 5 respectively on the Micromite (IC1).

The programming output on the Microbridge is only active when it is in programming mode, so the Microbridge does not interfere with the Micromite when it is using pins 4 & 5 as general purpose I/O pins.

Switch S1 is used to select programming mode and LED1 indicates the mode (lit solid when in programming mode).

CON2 is the main I/O connector for the Micromite and is designed so that it can plug into a solderless breadboard for prototyping. The connector also makes it easy to add a third PCB to the LCD BackPack "stack" which can carry circuitry specific to your application (such as amplifiers, relay drivers etc). This connector is wired identically to the original BackPack.

The Micromite communicates with the LCD panel using an SPI interface where pin 3 on the Micromite feeds

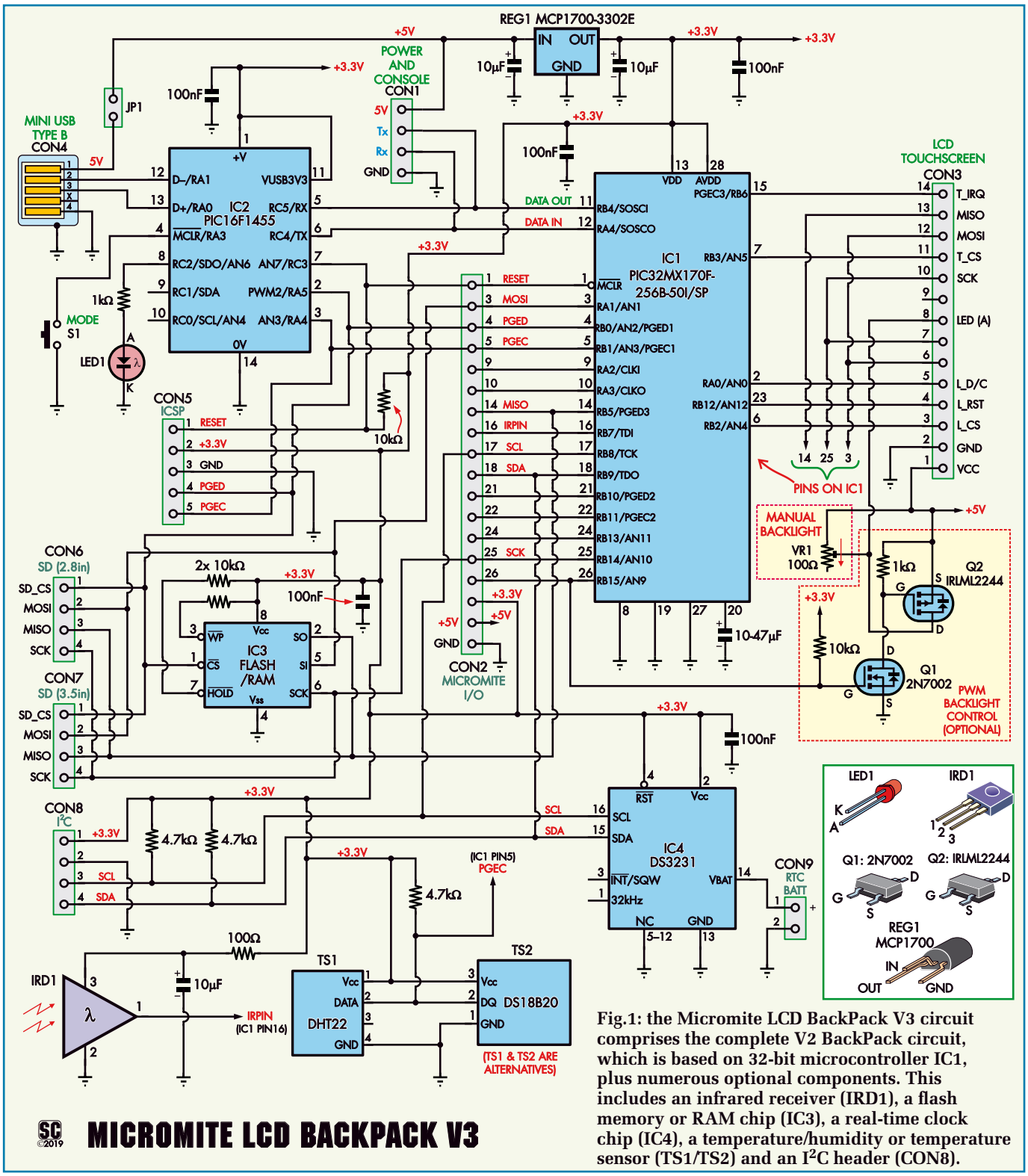


Fig.1: the Micromite LCD BackPack V3 circuit comprises the complete V2 BackPack circuit, which is based on 32-bit microcontroller IC1, plus numerous optional components. This includes an infrared receiver (IRD1), a flash memory or RAM chip (IC3), a real-time clock chip (IC4), a temperature/humidity or temperature sensor (TS1/TS2) and an I²C header (CON8).

SC ©2019 **MICROMITE LCD BACKPACK V3**

data to the LCD while pin 25 provides the clock signal. When the Micromite pulls pin 6 low, it is communicating with the LCD panel, and when pin 7 is pulled low, the Micromite is communicating with the touch controller on the display panel.

The 28-pin Micromite has only one SPI port and so pins 3, 14 & 25 (SPI data and clock) are also made available on CON2 so that you can also use this SPI serial channel to communicate with external devices.

Backlight control

You have two choices for controlling the brightness of the LCD's backlight. The first is to fit Mosfets Q1 and Q2 to the PCB, along with their associated resistors (this area is marked with a box on the PCB).

When you do this, PWM output 2A on the Micromite is used to control the backlight brightness from within your program. This is described in more detail later.

Alternatively, as with the original BackPack, you can fit VR1, a 100Ω trimpot. This is in series with the power to the backlight LEDs, so it limits the current drawn by them and therefore sets the brightness. Note that you should install one set of components or the other (not both). You also have the option of fitting a link across VR1's pads to permanently set the backlight to full brightness.

The LCD panel has a 3.9Ω resistor in series with the backlight so you will not burn out the backlight if you set the PWM output to 100%, wind VR1 to zero ohms or link it out.

The power supply is derived from either the 5V connector pin on CON1 or if JP1 is installed, from USB connector CON4. Powering the Micromite LCD BackPack from USB power is handy during program development, but for an embedded controller application, you would typically remove the jumper from JP1 and supply 5V power via CON1.

Note that you should not try to power the BackPack from both CON1 and USB as you could cause damage to the USB interface on your computer.

The 3.3V power supply for both the Micromite and the Microbridge is provided by REG1, which is a fixed output regulator with a low dropout voltage suitable for use with USB power supplies. This supply is also made available on CON2 so you can use it for powering external circuits (to a maximum of 150mA).

Improvements

As mentioned above, one of the major improvements with the BackPack V2 is that you can use either a 2.8in 320x240 pixel touchscreen or a 3.5in 480x320 pixel touchscreen. The board is sized to fit the larger screen. It still fits comfortably inside a UB3 jiffy box, the same box which we've used to house several Micromite BackPack based projects over the years.

We have also designed the board so that with both screen options, the onboard SD card socket is wired up to IC1. While the Micromite Plus software has read/write support for SD cards, it will not work on any through-hole PICs. The regular Micromite code, which works on our 28-pin DIP chip, does not natively support SD cards.

However, it would be possible to write BASIC code (or perhaps a CFUNCTION) to access an SD card with the regular Micromite, so we decided to wire up the SD card socket that already exists on the touchscreen module.

This extra header also helps to hold the touchscreen squarely onto the BackPack module without needing mounting hardware. The SD card is connected to the same SPI interface that's used to drive the touchscreen, but it has a separate CS line, which is connected to pin 4 on the Micromite. If you don't insert an SD card, it won't have any effect on this pin so it can be used for other purposes.

We decided that as long as we were making these changes, we should add some other useful features at the same time.

Added features

The BackPack V3 has provision for many extra onboard components which provide various useful functions. None of these need to be fitted; if you leave them off, the board will work much the same as the V2 BackPack, except for the option of the larger screen and SD card access.

These optional extra components can be used to add extra features to your Micromite project without needing to add another board or module. They are:

1) 3.3V Infrared receiver (IRD1). This mounts near the edge of the board, so that its leads can be bent to face out-

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wards for convenient remote control of the unit. Its supply is filtered for reliable operation. Its output is connected to Micromite pin 16, which is the MMBasic IR input pin, making it trivial to receive remote control commands in BASIC.

The IR receiver should ideally be a 3.3V type such as the Vishay TSOP2136 or TSOP2138. Having said that, we have used 4.5V receivers such as the Jaycar ZD1952 on a 3.3V supply and found they normally work satisfactorily.

2) Serial flash memory or static RAM, in either an 8-pin DIP or SOIC package (IC3). If you aren't using the SD card interface, you can fit a flash or SRAM chip with a standard pin-out to the board and use this to store configuration data, logging data, temporary working data etc.

These chips are easier to drive than SD cards; the BASIC code to access them is easy enough, and we provide a sample sketch to do this.

The memory chip's SPI interface is connected to the usual SPI pins on the Micromite, while the chip select line ($\overline{CS}$, pin 1) goes to pin 4 of IC1, same as for the SD card. That is why you can't use both at the same time.

If fitting this chip, you have the option to fit either or both of the pull-up resistors on pin 3 (write protect/$\overline{WP}$) and pin 7 ($\overline{HOLD}$). These may be required to read and write data on the chip. We've also provided for a 100nF supply bypass capacitor; always a good idea.

When purchasing a chip for this board, make sure its pin-out matches that shown and that it can run off a 3.3V supply. This is by far the most common pin-out for 8-pin serial memory chips and they will virtually all operate from 3.3V, but it's best to check.

3) A 4-pin header which connects to the I^{2}C bus and 3.3V power supply (CON8). A pair of 4.7kΩ pull-up resistors are also provided on the SCL and SDA lines, although these can be left out if pull-ups are provided externally.

The pinout of CON8 matches the commonly available BMP180/BMP280 temperature and atmospheric pressure sensor modules, as well as the BME280 temperature/pressure/humidity module. So any of these can be soldered directly to the BackPack at CON8.

Alternatively, a four-way header can be fitted and leads run to one of the many commonly available Arduino compatible I^{2}C modules, such as character LCD screens and other sorts of sensors.

4) A DS3231 real-time clock IC which also uses the I^{2}C serial bus (IC4). It too has a 100nF bypass capacitor and a header (CON9) to connect a back-up battery so that the time and date are maintained even when the board has no external power. Micromite BASIC has built-in commands for I^{2}C-based real-time clocks, so this is another feature that can be used easily.

The I^{2}C pull-up resistors need to be installed if a DS3231 chip is installed, unless they are already present on another connected module.

5) A DHT22 one-wire temperature and humidity sensor (TS1) or a DS18B20 one-wire digital temperature sensor (TS2). These connect to pin 5 of IC1, and there is provision for the required 4.7kΩ pull-up resistor too.

Data from the DHT22 can be read by a CFUNCTION which is available for download with the Micromite firmware, while there is a built-in BASIC function to read the temperature from a DS18B20.

If fitting a DHT22, it's best to lay it over on its side over the top of the DS18B20 footprint to allow a display to fit above.

Software support

As noted above, we have written CFUNCTIONs to provide support for the 3.5in display; 2.8in and smaller displays based on the ILI9341 are natively supported by the Micromite.

The CFUNCTIONs for the 3.5in displays 'hook into' the existing graphics commands, so once the display has been initialised, the drawing commands are the same. If you have already written some MMBasic software, you only need to add a few lines at the start to support the higher-resolution 3.5in display.

The other great thing about our CFUNCTIONs is that they do not take complete control of the SPI bus, allowing other SPI devices to be used.

Unfortunately, these CFUNCTIONs interfere with the touch controller's BASIC functions, so we have had to write a separate set of CFUNCTIONs to handle the touch panel.

Most of the other optional components mentioned above are already supported by MMBasic, so we didn't need to write much more code to allow you to use all the new features of the V3 BackPack. The only thing that is not natively supported is the flash or SRAM memory IC, for which we've written some demonstration code, as mentioned earlier.

High-value ceramic capacitors

Previous Micromites have required between one and three capacitors which were either specified as SMD 'chip' ceramics (10µF) or through-hole tantalum capacitors (47µF). This is because of the strict ESR requirements for some of the parts; 10µF tantalum capacitors often had too high an ESR to work reliably.

Some people didn't like having to solder the chip capacitors, and tantalum capacitors are more expensive and can be less reliable. Since then, through-hole 10µF ceramic capacitors have become available, and they use our preferred dielectric too (X7R). So we have specified those in the parts list. The other two options are still valid and can be used instead, if you prefer.

Construction

We'll start by assembling the basic V3 BackPack (effectively equivalent to the V2 BackPack), and then we'll describe what parts to add if you want to use any of the optional features. Refer to Fig.2, the PCB overlay diagram, to see which parts go where.

Start by fitting the surface-mount components. This includes the mini-USB socket, CON4, and possibly some of the capacitors as well as Mosfets Q1 and Q2 for PWM backlight control.

The pads for the mini-USB socket have been extended to make them easier to solder. Line the small posts in the underside of the socket up with the holes in the PCB; this should make everything else correspond. If so, solder one of the large mechanical pads in place to keep the socket in position and flush against the PCB.

Now apply some flux to the pads for the electrical connections. You should be able to touch the iron to the pad extensions, allowing the solder to run up to the pins on the socket. Ensure that the four pins are well attached and not bridged. If there are any bridges, carefully remove with solder wick. The pin with the shorter pad is not used in this application and does not need to be soldered.

Solder the remaining mechanical pads to complete the attachment of the socket. Double check your work, as it will be difficult to access the pins later

Parts list – MicroMite BackPack V3

(to provide the same functions as the V2 BackPack)

1 double-sided PCB, coded 07106191, 99 x 54.5mm
1 mini USB type B socket, SMD (CON4) [Altronics P1308]
1 SPST momentary tactile pushbutton (S1)
1 28-pin narrow (0.3in) DIL socket for IC1
1 14-pin DIL socket for IC2 (optional)
1 4-way header (CON1) (Micromite UART breakout; optional)
1 18-way straight header (CON2)
1 14-way female header (CON3)
1 5-way right-angle header (CON5) (for ICSP; optional)
1 4-way female header (CON6 or CON7)
1 2-way header and jumper shunt (JP1)
8 M3 x 6mm panhead machine screws (for mounting LCD)
4 M3 x 12mm tapped spacers (for mounting LCD)
1 2.8in or 3.5in LCD touch panel
[eg, Silicon Chip Online Shop Cat SC3410]
1 UB3 Jiffy Box (optional) with laser-cut acrylic lid
[Lid only: Silicon Chip Online Shop Cat SC5083]

Semiconductors
1 MCP1700-3302E/TO, TO-92 (REG1)
1 PIC32MX170F256B-50I/SP programmed with MMBasic firmware, narrow DIP-28 (IC1)
[Silicon Chip Online Shop Cat SC4262]
1 PIC16F1455-I/P programmed with the Microbridge firmware, DIP-14 (IC2)
[Silicon Chip Online Shop Cat SC4263]
1 3mm red LED (LED1)

Capacitors
3 10µF 16V X7R multi-layer ceramic capacitors (3216/1206 SMD or dipped leaded*) ***OR***
2 10µF 16V tantalum AND 1 47µF 16V tantalum
3 100nF 50V MKT polyester or multi-layer ceramic

Resistors (all 1/4W, 5%)
1 10kΩ 1 1kΩ

Optional parts for PWM backlight control
1 2N7002 N-channel Mosfet, SOT-23 (Q1)
1 IRLML2244TRPBF P-channel Mosfet, SOT-23 (Q2)
1 10kΩ 1/4W, 5% resistor
1 1kΩ 1/4W, 5% resistor

Optional parts for manual backlight control
1 100Ω 1/2W mini horizontal trimpot

Optional parts for infrared reception
1 three-pin 3.3V‡ infrared receiver (IRD1) [eg TSOP2136]
1 10µF 16V X7R multi-layer ceramic or tantalum capacitor (3216/1206 SMD or dipped leaded*)
1 100Ω 1/4W, 5% resistor *‡see text*

Optional parts for external RAM or flash memory
1 SPI RAM or flash IC, DIP-8 or SOIC-8 (IC3) [eg, 23LC1024 RAM or AT25SF041 flash; pinout as in Fig.1]
1 100nF 50V MKT polyester or multi-layer ceramic capacitor
2 10kΩ 1/4W, 5% resistors

Optional parts for real-time clock
1 DS3231 RTC IC, SOIC-16 (IC4)
1 100nF 50V MKT polyester or multi-layer ceramic capacitor
2 4.7kΩ 1/4W, 5% resistors
1 2-pin header for CON9 (optional)
1 2.3-5.5V battery [eg, CR2032 lithium button cell; Jaycar Cat SB1762]

Optional parts for temperature/humidity sensor
1 DHT22 digital temperature and humidity sensor (TS1) ***OR***
1 DS18B20 digital temperature sensor, TO-92 (TS2)
1 4.7kΩ 1/4W, 5% resistor

Optional parts for external I²C interface
1 4-pin header (CON8)
2 4.7kΩ 1/4W, 5% resistors ^

^ These resistors shared with RTC above.

Optional parts for temperature/pressure/altitude sensor
1 GY-68 BMP180 temperature/pressure sensor module (Silicon Chip Online Shop Cat SC4343) ***OR***
1 GY-BMP280 temperature/pressure sensor module (Silicon Chip Online Shop Cat SC4595) ***OR***
1 GY-BME280 temperature/pressure/humidity sensor module (Silicon Chip Online Shop Cat SC4608)
1 4-pin header (CON8)
2 4.7kΩ 1/4W, 5% resistors ^

* eg, Mouser Cat 810-FA26X7R1E106KRU6 or Digi-Key Cat 445-173437-1-ND

Resistor Colour Codes (quantites vary depending on options fitted)

	Value	4-Band Code (1%)	5-Band Code (1%)
❑	10kΩ	brown black orange brown	brown black black red brown
❑	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1kΩ	brown black red brown	brown black black brown brown
❑	100Ω	brown black brown brown	brown black black black brown

with the other components installed.

If you are using SMD capacitors, they will all be the same type, but the two transistors are not. Check that these are not mixed up before soldering them in place.

For the other SMD components, which are all quite small, an easy way to fit these is to apply solder to one of the pads then hold the component on top with tweezers. Apply the iron again to allow the solder to melt onto the component lead. This avoids having to handle three things at the same time.

If necessary, adjust the location of the parts so that the pins are fully lined up with the pads, and when you are happy, apply some solder to the remaining pins. Finally, go back and retouch the first pin to relieve any stress in the solder.

Through-hole parts

The remaining components can be added in the usual order. Fit the 10kΩ resistor between IC1 and IC2 and the 1kΩ resistor near LED1. Check these values with a multimeter if you are not sure, although the circuit would probably still work if they were swapped!

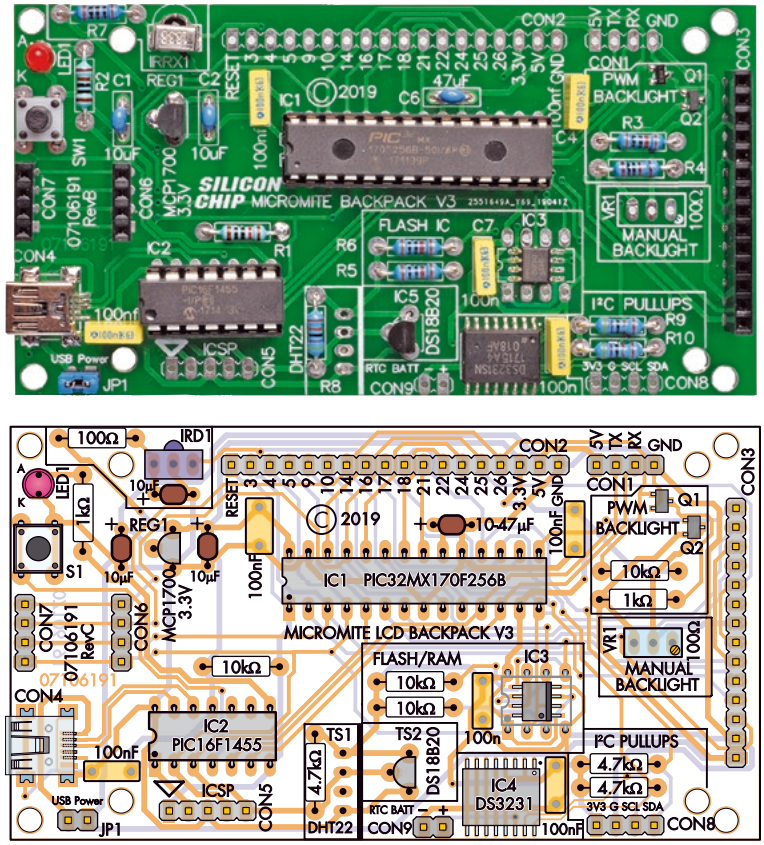


Fig.2: the slightly larger V3 BackPack PCB can accommodate a 2.8in (320x240 pixel) or 3.5in (480x320 pixel) LCD touchscreen, using the inner or outer set of four mounting holes respectively. Both screens share the CON3 I/O and power connector while CON6 makes electrical connections to the SD card socket on the smaller display, and CON7 on the larger display. CON2, the I/O header, is identical to that of the two earlier BackPack designs.

The tactile switch sits near the left-hand edge of the board. Ensure it is pushed down firmly against the PCB before soldering its pins. It may take some force, but should pop into place

. JP1 can also be fitted, below the USB socket. Unless you are powering the BackPack from an external 5V power supply, the jumper shunt will need to be fitted to source power from the USB socket.

The other headers should be fitted now. You will probably only need to install one of CON6 or CON7, depending on whether you are using a 2.8in or 3.5in display, although you can fit both if you wish to experiment.

It's a good idea to temporarily fit the headers onto the display you are using during soldering as this will keep the headers aligned squarely and correctly. CON3 can be fitted at the same time, to simplify lining up the display with the BackPack.

All that is left is to install the semiconductors. LED1 is mounted with its cathode (flat side) towards the USB socket. Ensure REG1's outline matches the footprint on the PCB and solder it down close to the PCB.

If you are using PWM backlight control, the two resistors below Q1 & Q2 must be fitted. Their values are marked on the silkscreen, and they should be checked with a multimeter too.

Alternatively, you can fit potentiometer VR1 for manual backlight control, or a wire link as shown in our photo (below right) if you prefer to have the backlight fully on all the time.

If your potentiometer is more than 9mm tall, it may foul the display PCB and can be laid over in the space set aside if necessary.

Solder the capacitors next. If you are using tantalum capacitors, then the larger 47µF capacitor goes next to IC1, while the two 10µF capacitors sit either side of REG1. Tantalum capacitors are polarised, so take care that the positive leads (generally marked on the body) go to the pads with a "+" sign.

If you are using ceramic capacitors instead, their polarity does not matter and you can use a 10µF ceramic in place of the 47µF tantalum, ie, all three high-value capacitors will be the same type.

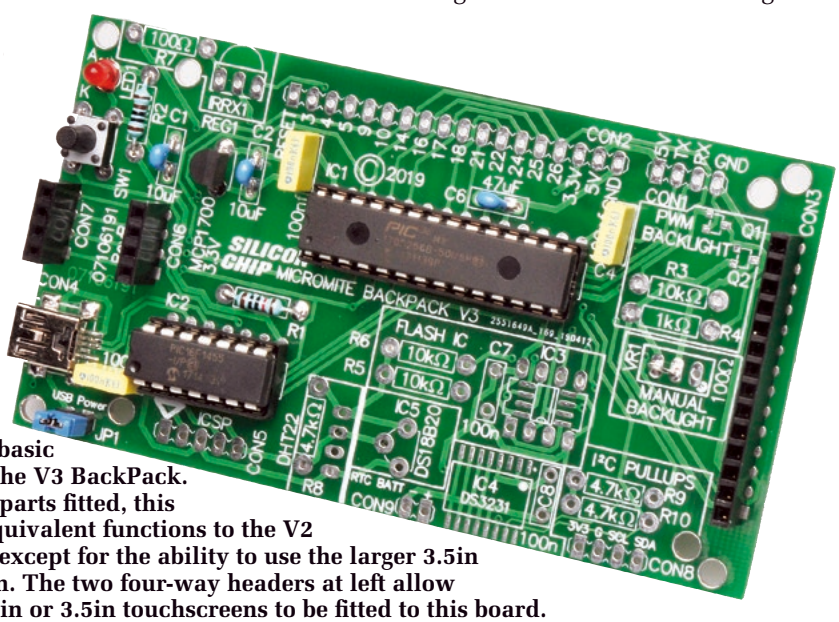
There are also three MKT or multilayer ceramic through-hole capacitors to fit. Solder them in place and trim their leads.

Fit the two IC sockets next, if you are using them. These are a good idea in case you need to replace one of the chips. The notches on both face to the left, towards the USB socket. Note that if you do use sockets, IC2 will touch the underside of the SD card socket on the 3.5in display. This shouldn't cause any problems, but it can be avoided by separating the boards with 12mm tapped spacers.

Fitting the optional components

The parts list mentions what components you need to populate each optional add-on section.

These are all through-hole parts, except for the flash IC (IC3), which can be a through-hole or surface-mounting



This is the basic version of the V3 BackPack. With these parts fitted, this provides equivalent functions to the V2 BackPack, except for the ability to use the larger 3.5in touchscreen. The two four-way headers at left allow either a 2.8in or 3.5in touchscreens to be fitted to this board.

Using the optional components

Using the infrared receiver (IRD1)

MMBasic only supports an infrared receiver on pin 16 of the 28-pin PIC32, so that is where we have connected it. You therefore lose this pin as a general purpose I/O when you fit IRD1.

MMBasic can trigger a software interrupt when a valid command is received and then call a user-defined subroutine. This is set up as follows:

```
IR DevCode, KeyCode, IR_Int
```

DevCode and KeyCode specify the variable names which will contain the device and key codes respectively when the user routine ("IR_Int" in this case) is called. So you could define the function like this:

```
SUB IR_Int
 PRINT  "DEVICE:" DevCode "KEY:" KeyCode
END SUB
```

Using the real-time clock

MMBasic has built-in routines to use an RTC module connected to the hardware I²C pins, as is the case here. Set the Micromite's internal clock from the DS3231 IC thus:

```
RTC GETTIME
```

Setting the time on the DS3231 is done with a single command specifying the current date and time:

```
RTC SETTIME year, month, day, hour,
  minute, second
```

If you are using any other I²C devices, you can connect them via CON8. If, as is often the case, the module(s) have their own pull-up resistors, either remove them or omit the onboard I²C pull-up resistors. It may work with both in place, but this is not recommended

Temperature and humidity sensors

The temperature from a DS18B20 (TS2) can be read with a single MMBasic command:

```
TEMPERATURE = TEMPR(5)
```

Functions for communicating with a DHT22 were built into early versions of MMBasic, but have been removed in later versions; instead, a CSUB is supplied to do the same job. The required code and documentation can be found in the "Humid.pdf" file in the "Embedded C Modules" subfolder of the Micromite firmware download, available from **http://geoffg.net/micromite.html#Downloads**

After the CSUB has been copied into the BASIC program, the temperature and humidity can be read by a single command like this:

```
HUMID 5, TEMPERATURE, HUMIDITY
```

The first parameter (5) tells this function which Micromite pin the DHT22 sensor is connected to. The results are saved in the TEMPERATURE and HUMIDITY variables. Due to the way the DHT22 works, the results are actually from the previous time this command was issued, with the current call starting the next conversion in the background.

Therefore, you will need to ignore the values of TEMPERATURE and HUMIDITY the first time you call this command. Hence, it's a good idea to issue it during your initialisation routine.

Using a RAM chip

We test-fitted our board with a 23LC1024 RAM IC (IC3). It's similar to the 23LCV1024 used in the 433MHz Wireless Range Extender project in the May 2017 issue (see **siliconchip.com.au/Article/11615**).

There is no $\overline{WP}$ (write-protect) function on the RAM IC, but it does have a $\overline{HOLD}$ pin which needs to be held high, so the 10kΩ pull-up resistors are still required.

We've written a sample program to demonstrate using such a chip, which is named "23LC1024 RAM IC.bas". It simply writes data to the chip, based on the contents of the TIMER variable, then reads those values back and prints them out on the Micromite terminal.

The CS pin of IC3 is hardwired to the Micromite's pin 4, and this is set as a constant at the start of the sample program. The SETRAMMODE subroutine provides page, byte and sequential options. Using the sequential option means that the entire RAM contents can be read or written in one pass.

A read or write starts with a STARTRAMREAD/STARTRAMWRITE command, which pulls CS low and sends a command sequence containing the supplied start address.

After that, subsequent calls to RAMREAD or RAMWRITE read or write a single byte before incrementing the address pointer. The sequence ends with a call to ENDRAMREAD/ENDRAMWRITE which brings CS high, releasing the SPI bus.

Using external flash memory

For testing out the flash interface, we tried an AT25SF041 4Mbit (0.5MB) flash IC (again, as IC3). On this chip, the $\overline{WP}$ and $\overline{HOLD}$ pins are internally pulled high, so the 10kΩ resistors are not needed, although they were fitted to our prototype; it doesn't hurt to have both internal and external pull-ups.

Writing to the device is a bit more complicated than for a RAM chip, but reading uses the same command and format as the RAM IC.

Flash memory cannot usually be written byte by byte. An entire 'page', 4KB in this case, must be erased (set to all 1s), then data can be written byte by byte (or 'programmed' according to the data sheet terminology). Writes occur in blocks of up to 256 bytes. The data to be written is actually stored into a RAM buffer; it isn't written to flash until the CS line goes high, at the end of the process.

There are a few more details than what's described here; so the device data sheet is a good place to check out the subtleties of the process. One wrinkle, for example, is that the writes will wrap around at addresses that are multiples of 256 bytes. There is also a software flag (WEL; write-enable latch) that must be set before any changes (erase or write) can occur to the flash memory contents.

Thus a typical write sequence would consist of setting the WEL flag, erasing a page, setting the WEL flag again and then writing the actual data.

The sample program is called "AT25SF041 FLASH IC.bas". Unlike the RAM demo, which loops continuously, this program reads the flash once, writes data to the flash once, then rereads it, displaying the results on the terminal. This is to avoid wearing out the flash.

The flash chip we used has a minimum endurance of 100,000 cycles, which means that it would take 27 hours at one write per second (to the same part of the flash memory) to potentially cause a failure.

Using a BMP180, BMP280 or BME280 sensor module

We published an article in the December 2017 issue explaining how to use a BMP180 or BMP280 module with a Micromite; see **siliconchip.com.au/Article/10910** You can download the sample BASIC code for free from **siliconchip.com.au/Shop/6/4521**

While the BMP180 and BMP280 provide temperature and pressure/altitude information, the BME280 also includes humidity data. You can find MMBasic source code to read data from a BME280 sensor at TheBackShed forum. See: **www.thebackshed.com/forum/forum_posts.asp?TID=8362**

Driving the 3.5-inch touchscreen

When using the 2.8in touchscreen, you set it up once using the OPTION command (as described in the main text) and from then on, the Micromite automatically configures it each time the chip is powered up. But because MMBasic doesn't natively support the 3.5in touchscreen, setting it up is a bit different.

You need to run some code at the start of your program, every time the chip is powered up, to configure this display. This code initialises the display and also sets up the 'hooks' into Micromite BASIC's graphics commands so that you can draw to this screen using the same commands as for the 2.8in display.

One big difference of this implementation is that it does not block use of the SPI pins to other interfaces. In fact, the user program must start the SPI peripheral just as for any other interface. This is also the reason why the in-built touch commands won't work, as they too require exclusive use of the SPI interface.

Although the various control pins for the LCD and touch controllers (such as $\overline{CS}$, DC and RESET) are hardwired into the CFUNCTION to match the hardware that is on the BackPack, they need to be set up by the user program. The advantage here is that control can be taken back if your program wants to use these pins for other purposes.

The CFUNCTION assumes that all this setting-up has been done, and will fail if it has not. This is so that the CFUNCTION has minimal overhead and is thus quite fast. This is handy, as the 3.5in displays have twice as many pixels to manage as the 2.8in displays.

The following code needs to appear before the display functions can be used with the 3.5in display. You can also find this code in our example programs:

```
DIM INTEGER ROTATION=1,BUCKET,
  ILI9488_SPI_ADD
ILI9488_SPI_ADD=PEEK(CFUNADDR ILI9488_SPI)
SPI OPEN 20000000,0,8
SETPIN 2,DOUT
SETPIN 23,DOUT
SETPIN 6,DOUT
BUCKET = ILI9488_SPI(ILI9488_SPI_ADD,
  ROTATION)
```

The first line defines three integer variables. ROTATION sets the display orientation. Set it to a value between one and four. Mode one is portrait, two is landscape, three is upside-down portrait and four is upside-down landscape.

BUCKET (the 'bit-bucket') is used as a place to store the return value of the CFUNCTION. BASIC insists on us storing the return value of a function when calling it, so even though we don't need to use that return value, we need somewhere to store it.

ILI9488_SPI_ADD is used to hold the flash memory address (shortened to "ADD") of the CFUNCTION. This needs to be passed to the CFUNCTION during the initialisation stage, as it needs this to set up the hooks into the native graphics functions.

The address of the CFUNCTION is retrieved by using the PEEK function on the second line. We have called the CFUNCTION "ILI9488_SPI", so if you change this, you will need to change that second line too.

The next four lines set up the micro's SPI peripheral and set up the I/O pins used to control the screen's $\overline{CS}$, DC and RESET lines.

Finally, the display is initialised by our CFUNCTION according to the ROTATION setting. After this, you will normally clear the screen using a command like this:

```
CLS(RGB(BLACK))
```

Our demonstration program, "ILI9488_SPI_minimal working.bas", can be downloaded from the Silicon Chip website. This sets up the display as described above and then draws some patterns on the screen using the inbuilt graphics functions.

Using the touch interface

As mentioned in the text, MMBasic's built-in touch panel support doesn't play well with our new driver. We suspect that this is because the display driver is not initialised when the touch controller attempts to start up at Micromite boot time. So we have written a separate CFUNCTION to provide the touch functions.

The "ILI9488 with touch calibration.bas" demonstration program (also in the download package on our website) shows how to read raw touch data and also calculate touch locations on the screen. As well as initialising the display controller as noted above, the following lines are required to use the touch controller:

```
DIM INTEGER TOUCH_X0,TOUCH_Y0,
  TOUCH_X1,TOUCH_Y1
TOUCH_X0=110
TOUCH_Y0=1993
TOUCH_X1=2001
TOUCH_Y1=76
SETPIN 7,DOUT
```

These four variables provide touch panel calibration. Our calibration sketch generates a new set of calibration values for a specific touch panel, which can be pasted back into your program.

The ROTATION variable also needs to be set, as described earlier, since the calibrated touch coordinates depend on the display rotation that is being used.

The last line sets up the Micromite pin used to drive the touch controller's $\overline{CS}$ (chip select) line.

To retrieve the x-axis component of the current touch position, use the following CFUNCTION call:

```
X=XPT2046(0,ROTATION,TOUCH_X0,TOUCH_Y0,
  TOUCH_X1,TOUCH_Y1,MM.HRES,MM.VRES)
```

This CFUNCTION requires no initialisation, although it assumes that the SPI interface has already been set up, as this is required to use the display anyway. This CFUNCTION reduces the speed of the SPI bus below the 2.5MHz limit of the touch controller IC for the duration of the CFUNCTION, and returns it to its previous value afterwards.

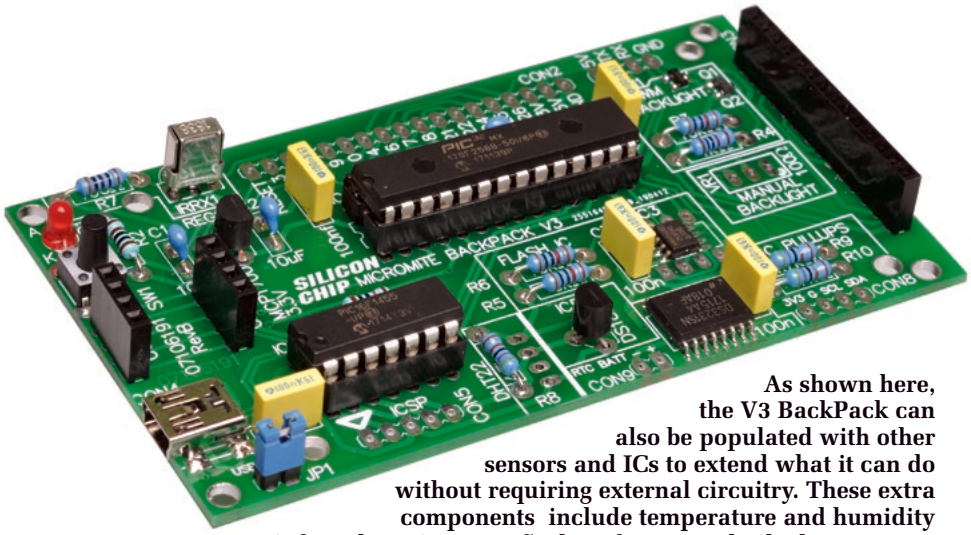
To read the y-axis, the value of one is passed as the first parameter instead:

```
Y=XPT2046(1,ROTATION,TOUCH_X0,TOUCH_Y0,
  TOUCH_X1,TOUCH_Y1,MM.HRES,MM.VRES)
```

To retrieve the raw ADC values (which are necessary for the calibration), values of two, three or four are passed as the CFUNCTION's first parameter. The z-axis value (with the first parameter as four) corresponds to the pressure on the touch panel, and is used by our function to check whether a valid touch is occurring. For example:

```
RAWX=XPT2046(2)
RAWY=XPT2046(3)
RAWZ=XPT2046(4)
```

By using the z-axis value, the IRQ pin on the touch controller is not needed for the 3.5in displays, although it is left connected on our board, for use with the 2.8in displays.



As shown here, the V3 BackPack can also be populated with other sensors and ICs to extend what it can do without requiring external circuitry. These extra components include temperature and humidity sensors, an infrared receiver or a flash IC for non-volatile data storage.

type, and the DS32321 IC (IC4), which is only available in a surface-mounting package.

If fitting IRD1, you also need to mount the adjacent 100Ω resistor and 10µF capacitor used to filter and bypass its supply.

It's a good idea to mount IRD1 with long enough leads that you can bend its lens to face in the same direction as the screen. It can be soldered on either side of the PCB, as long as its lead connections are not reversed compared to what is shown in Fig.2.

To fit IC4, the DS3231 IC, apply a small amount of flux to the pads and solder one pin in place. Check that its pin 1 dot is orientated as shown in Fig.2. Once you are happy that the part is flat and lined up with the other pins, carefully solder the rest. Ensure that no solder bridges have formed; if necessary, clean them up using flux paste and solder braid (wick).

You will also need to fit the adjacent 100nF capacitor and both I²C pull-up resistors (4.7kΩ). It's also a good idea to connect a battery (2.3-5.5V) via CON9. A CR2032 lithium battery is commonly used with the DS3231 and will last many years.

You can either solder its leads to the pads for CON9 or fit a pin header and connect the battery using patch leads or similar. If you don't connect a battery, IC4 will lose its time each time power to the board is cut.

But there isn't much room for a battery on the PCB, and no mounting location is provided, so you will have to figure out how to mount it (eg, with double sided tape) and wire it back to CON9. If mounting it somewhere on this PCB, make sure it's properly insulated so it can't short to any of the tracks or components.

Either the DHT22 (TS1) or DS18B20 (TS2) temperature sensor can be fitted, but not both. They connect to the same pin on the Micromite (pin 5) but use different communication protocols. They share a single 4.7kΩ pull-up resistor, which is inside the box labelled TS1, but needs to be fitted if either TS1 or TS2 is being installed.

TS1 is quite tall so it can be fitted laid over towards IC4; the vented side of the case should face away from the

Breaking news from The Back Shed

While we were preparing this article, Geoff Graham told us that Peter Mather had made a post on his forum, "The Back Shed", describing a driver that he had created for the ILI9488 display controller.

The Back Shed is a great place to get information on the various Micromites and other topics. See: **www.thebackshed.com/forum/**

His code for the display controller can be found at: **www.thebackshed.com/forum/forum_posts.asp?TID=11419**

It is implemented as a CSUB which is run by the Micromite at startup. The initialisation process is different to our CFUNCTION, but after that, you use the same native graphics commands as with our code.

The code shown on the forum is for a different Micromite board, so the initialisation line needs to be changed to suit the pinouts used on the BackPack. Copy and paste his code labelled "MM2" into a blank program, then change the second line from:

```
ILI9488 16,2,9,1
```

to:

```
ILI9488 2,23,6,1
```

These parameters determine the display CD pin, RST pin, $\overline{CS}$ pin and orientation. This changes the pin values to suit the BackPack. The orientation is a value from 1 to 4, as explained in the main text of this article. Upload the program to the Micromite and run the command:

```
LIBRARY SAVE
```

to store the CSUB as a library instead of BASIC code, then restart the processor with the command:

```
WATCHDOG 1
```

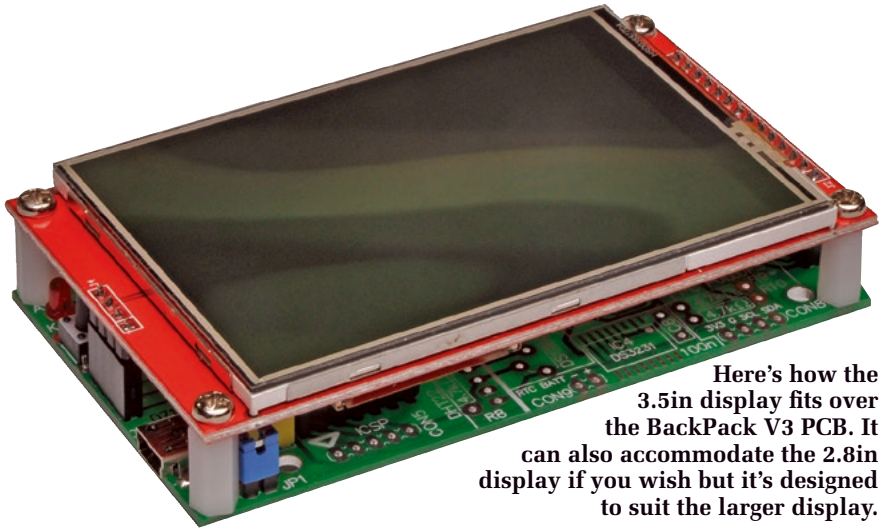
The driver will then be loaded. At this stage, the Micromite is at the same state as if the OPTION LCDPANEL command had been run for the 2.8in screen, and normal touch panel initialisation can continue, like this:

```
GUI TEST LCDPANEL
OPTION TOUCH 7,15
GUI CALIBRATE
GUI TEST TOUCH
```

Readers who are comfortable with the usual way of setting up touch panels on the Micromite, such as the ILI9341, may prefer this method as it works similarly. However, note that you will lose the ability to use the SPI peripheral for other purposes, as is the case with the 2.8in display.

Peter also noted the glitch with the MISO pin on these displays which we found (and worked around) while while trying them out in our May article and then on the V3 BackPack board; see: **siliconchip.com.au/Article/11629**

Finally, future releases of the Micromite V2 firmware will include a copy of Peter Mather's ILI9488 CSUB driver.



Here's how the 3.5in display fits over the BackPack V3 PCB. It can also accommodate the 2.8in display if you wish but it's designed to suit the larger display.

PCB. If IC4 has already been fitted, there should still be room to lay TS1 on its side, but you will need to initially mount it slightly above the board so that it will sit flat on top of IC4 when bent over.

If fitting an SMD flash or RAM chip for IC3, orientate it with pin 1 towards the bottom edge of the board, as shown in Fig.2. You can solder it using a similar technique as described for IC4 above.

The through-hole version will be a bit easier to solder, and is orientated with its pin 1 dot or notch towards the left as shown.

In either case, you will also need to fit the adjacent 100nF bypass capacitor and the two 10kΩ pull-up resistors. Note that some flash ICs have internal pull-ups; in this case, you can omit those resistors. Check your device's data sheet to find out.

To connect an external I^2C module, including a BMP180 (GY-68 module), BMP280 (GY-BMP280 module) or BME280 (GY-BME280 module), fit pin header CON8 and the two 4.7kΩ resistors above it. As mentioned earlier, you can solder the module directly to CON8; match up its pinout, as printed on the module, with that shown in Fig.2 or on the PCB.

Note that some modules already incorporate pull-up resistors for the SDA and SCL lines. In this case, either don't fit the resistors on the BackPack, or remove them from the module. There should be exactly one set of pull-up resistors in the circuit.

Programming the chips

Both chips are available pre-programmed from the SILICON CHIP ONLINE SHOP, but you only really need IC2 to be pre-programmed since it is capable of loading the software onto IC1, using pic32prog (see below). But having IC1 pre-programmed will save you some effort, and both chips come programmed if you purchase them as part of our kit (Cat SC5082).

While it is possible to program IC2 using a BASIC program on IC1 and a 9V battery, we only recommend this if you have no other way, and this has a bit of a 'chicken and egg' problem, in that it only works if IC1 has already been programmed.

See **http://geoffg.net/microbridge.html** for more information on this technique.

You can program IC1 after fitting it, either using the ICSP header (CON5) and a PICkit or similar programmer, or by using IC2 in its Microbridge role. More information on using the Microbridge and its pic32prog software can be found in the article from May 2017 (**siliconchip.com.au/Article/10648**).

We'll proceed assuming that you have pre-programmed chips, so fit them now. If you have used sockets, gently bend the leads of the ICs inwards to fit the sockets, otherwise, solder the chips directly to the PCB, taking great care that they are orientated correctly. Both ICs should have pin 1 facing towards the USB socket.

It's a good idea to solder two diagonally opposite corners and ensure the IC is flat and level before soldering the remainder.

The V3 BackPack is now usable and can be tested. Plug the BackPack into a computer and it should show up as a new USB-serial device.

Communication occurs at 38,400 baud on a freshly programmed Micromite, if you want to check this out now, using your favourite serial terminal program.

Drivers

Under Windows 10 and Linux, a driver should be automatically installed. If it is not, then the driver can be found at **www.microchip.com/wwwproducts/en/MCP2200** While this is a different device, it uses the same USB identification (VID and PID) codes as the Microbridge firmware.

(Incidentally, the MCP2200 is nothing more than a PIC18F14K50 that has been programmed to act as a USB-serial bridge, which is why this driver works).

When properly installed, the Micromite BackPack should appear as a new virtual COM port on your computer.

Configuring the display

The backlight controls work unchanged compared to the V2 BackPack (assuming you have fitted Q1, Q2 and their associated resistors).

The backlight intensity is set on a scale of 0 to 100 with the PWM function thus:

```
PWM 2,250,BACKLIGHT
```

This command works because pin 26 is the first output of PWM channel 2.

Alternatively, the backlight can be turned on or off by using the SETPIN and PIN commands to set the output of pin 26 high or low.

If you are using a 2.8in display, then the same instructions as given in the article from May 2017 (on the V2 BackPack) apply. The following commands initialise and calibrate the display:

```
OPTION LCDPANEL
  ILI9341,L,2,23,6
GUI TEST LCDPANEL
OPTION TOUCH 7,15
GUI CALIBRATE
GUI TEST TOUCH
```

The 3.5in panel works slightly differently, as it depends on a CFUNCTION to work and is not quite as 'transparent' as the inbuilt display driver.

See the panel titled "Driving the 3.5-inch touchscreen" for details on how to set up and use the larger screen.

If you have fitted any of the optional components, see the separate panel "Using the optional components" which describes the software required to use them. SC

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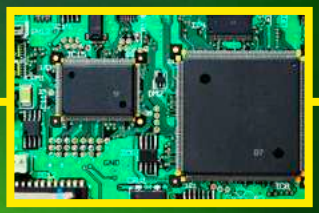

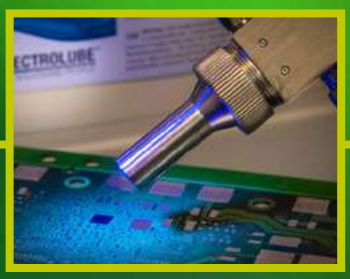

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In subsequent years, under the banner of the Historic Radio Society of Australia (HRSA), the event has ballooned into Australia's largest historical radio display and sales event. It alternates every two years with a similar large HRSA event in Melbourne.

This year, it will be a significant event, held on **September 20-22nd**, in the national capital's vast Exhibition Park (EPIC) at Mitchell, on Canberra's north side.

Highlights include dedicated activities for HRSA members on Saturday 21st, and a giant Sunday market on the 22nd, with a display and workshop open to the public.

Those who like to collect vintage radios, related posters and magazines, do repairs and restorations, plus anyone who likes to re-live the 'Golden Days' of radio, will gather for the biggest Vintage Radio show Australia has to offer.

One visitor referred to the last Radio-Fest as being like "a combination of Harvey Norman and Bunnings, circa 1937"!

Sunday's public open day will feature many displays of early radios, from very early broadcast receivers (including crystal sets), through to the beautiful and valuable high Art Deco period of Bakelite radios in the 1930s and 40s, plus the familiar timber cabinets of mantel and floor-style console radios, and early phonographs and telephones.

Many of the radios have been painstakingly restored to full working order, with cabinets in show-room condition.

These displays will be far outnumbered by for-sale tables which will feature all of the above, plus countless parts, literature, advertising material and ephemera of every kind.

Free workshops running throughout the morning will include a furniture maker, with tips on the restoration and finishing of timber cabinets, and our own experts speaking about and demonstrating seemingly impossible restorations.

There will also be a comprehensive introduction to understanding and repairing transistor radios.

A giant raffle will offer patrons the opportunity to bag one of three fully-restored radios from the golden age.

Parking at EPIC is excellent, and for interstate visitors, there are motels aplenty nearby, with EPIC's own caravan park offering another accommodation option.

Saturday's program for

in Canberra next month

By Richard Begbie and Kevin Poulter

members offers further delights. The morning sees a high-class auction of some of the rarest and most sought-after antique radio equipment. This is a highly selective catalog, filled with top-quality lots.

Already entered in the earliest category for this year's auction are two exceptional and beautiful Atwater Kent breadboard radios, other rare early sets, AWA "Empire States", and a host of other desirables.

There will be plenty of highly-collectable Bakelite radios, early literature, in-store advertising material and other bits and pieces on offer.

In the afternoon, members and partners are offered a free bus tour of selected Canberra sites of interest, and in the evening we join in a festive dinner. Once again, our friendly bus driver will pick up and drop off prospective diners from the selected accommodation.

Members can expect great food and entertainment, with ABC local radio host Alex Sloane as the speaker. Her many years in radio promise a wealth of quirky tales and nostalgia.

If you would like to "access all areas", especially Saturday's events and on Sunday, joining the society is easy. For just $40, membership also confers benefits beyond admission to the show.

This includes a subscription to Radio Waves, the superb colour quarterly journal of the society – a high-quality magazine packed with articles of technical, historical, and social interest, news from groups around the country, plus sixteen full pages of classifieds.

Members also gain access to the 50,000 valves in the Valve Bank, various other spares like high voltage capacitors and can participate in our exclusive auctions. The HRSA also has a range of technical journals and a circuit service.

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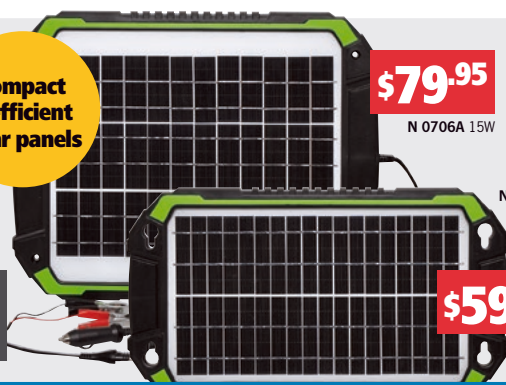

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Extended resolution to 4 digits! Offers everything the serious enthusiast could need with auto ranging, min/max/rel modes, frequency, duty cycle and non contact voltage detection. Includes carry case. **Q 1135**

Do-It-All Multimeter

With in-built AC mains detection. This is one of the best DMMs we have evaluated when it comes to build quality and feature set. Its perfect for the serious enthusiast or tradesperson • LCD bargraph • 3.75 digit display • Mode assistance indicators. • Includes carry case, temp probe & insulated test leads. **Q 1068**

Super-Tough DMM. Built like a tank!

This new multimeter is built tough with water and dust resistance, plus a impact resistant case for the rough and tumble of every day use in the field. Auto ranging design offers a feature list as long as your arm with a clear large digit backlit display. Includes carry case & test leads. See web for full spec list. **Q 1069**

Solder Fume Extractor

Whisk away solder fumes from your workspace instantly! Also works as a fan. Adjustable speed.

'Roadies' Cable Tester

Tests 13 types of leads for continuity. A real time saver! Tests: 6.35mm, DIN (3/5/7/8 pin), RCA, XLR (3/5 pin), Speakon (4P/8P), RJ45, USB & banana. Requires 9V battery (S 4970B $3.95).

Precision Screwdriver Set

Ideal for servicing! Features a driver handle & 19 pozi, hex, torx and blade tips.

Nifty Multi-Angle Bench Vice

Made from diecast alloy. Clamps to your work bench and provides total 360° freedom when working. Jaws open to 55 mm. Includes soft jaws for holding delicate connectors.

Never lose a tiny screw again!

This magnetic 25x20cm workmat & marker keeps tiny screws and washers in place when servicing.

Mini Hot Melt Glue Gun

Easy to use hot glue gun for use around the house, with crafts and hobbies. 12pk glue sticks $4.90 (T 2938A)

Zip Up Precision Tool Set

A combination of spring loaded pliers/cutters and ferrule top screw drivers in a tough folding carry case. Perfect for servicing in the field. All cutters and pliers have soft rubber handles for added comfort.

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Perfect for heatshrink - shrinks evenly without burning. Shifts paint, solvents from surfaces, makes plastics malleable, etc. 450L/min airflow.

Need a laptop charger for your workbench?

This 45W USB-C power delivery (PD) charger offers fast recharging for MacBooks, Nintendo Switch and other type "C" equipped devices. Also provides two type "A" USB outputs.

Blast away dirt & grime on parts

This is a true price breakthrough for a quality ultrasonic cleaner for your workbench. Great for cleaning small parts, jewellery, shaver heads, glasses and more! Shifts grease, dust and gunk from tiny crevices in just minutes. Tank size: 155x98x52mm.

Pliers for every need!

Outstanding value starter set for electronics. Includes side cutters, long nose pliers, curved long nose pliers, straight flat nose pliers and end type wire cutters.

Build & Create this August...

NEW!

Range of PLA filament to suit! 1kg rolls $39.95ea

$599

K 8400

NEW Core I3 Desktop 3D Printer Kit

Add 3D printing to your workbench to produce working prototypes, 'one-offs' & finished designs downloadable from the internet. From printing your own gaming pieces to cosplay parts and fixes for broken parts, this 3D printer adds incredibly versatility to your workbench.

Features: • 200x200x200 build volume • PLA filament • Pre-terminated cables for easy construction • Heated auto levelling print bed • Build time ≈4 hours

$79.95

K 8300

Create your own DIY art!

6 colour multi colour pack of filament K 8405 $24.95

3D Printing Pen

A crafty addition to any work space, this handheld pen extrudes 1.75mm PLA or ABS filament for decorating objects, plastic repair jobs or touch ups to 3D printed models. Easy to use with adjustable extrusion speed. Includes 12m of PLA filament.

Control more with 2 shields!

K 9670A

$120

NEW!

MK2 Arduino MegaBox Kit by Altronics.

Upgraded for 2019! Developed in house by Altronics, this new revised MegaBox is an upgrade of our original K 9670 - adding space for two shields, plus FIVE 2A 5V relay outputs and eight opto isolated outputs. All UNO/ Mega pins are broken out to header sockets for easy connection to other breakouts. A small 160 hole prototyping area is included for connecting to other sensors. *Arduino board & shields not included.

Tobbie II Robot Kit

Tobbie is back and he's had an upgrade! Now powered by the popular BBC micro:bit board, this new version has unlimited scope for self programming. Front screen displays text & symbols. Great for teaching kids coding. Requires 4xAAA batteries (S 4949B $9.95).

Age 8+

NEW!

$59.95

K 1150

Add on a Z 6440 micro:bit starter pack for $30!

NEW!

$49.95

Age 8+

K 1152

Scurrying Hedgehog Kit

This cute hedgehog toy kit bristles his spines when he hears a loud noise (such as a hand clap). He will even curl up and roll away if you scare him enough! Features light up eyes and motorised feet. Assembles in under 2 hours with no special tools required. Requires 4 x AAA batteries (S 4949B $9.95).

Age 8+

K 1154

NEW!

$44.95

5 In 1 Smart 'Coding Concepts' Robot Kit

This new kit features a central coding ring which can be tell the robot which direction to move and when to perform an action. Can be built and re-built 5 ways. Teaches kids about coding with no computers required! Requires 1xAAA battery.

Age 10+

Many more lab kits in store!

SAVE $40

$99

K 2208

130 in 1 Electronics Learning Lab

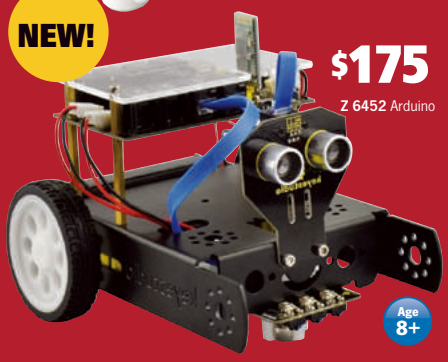
A comprehensive learning lab with many hours of building. Build a radio, broadcast station, organ, kitchen timer, logic circuits & more. Requires 6xAA batteries (S 4906A lithium 2pk $8.95).

$119

Z 6454 BBC Micro:bit

Requires Z 6440 micro:bit board $35.50

NEW!



$175

Z 6452 Arduino

Age 8+

Build & code your own robot with STEM Bot.

STEM bot is an easy to program 2 wheel obstacle avoidance and line tracking robot. Coding your program is easy using the standard BBC Micro:bit or Arduino software. Wiring and construction has been designed to be as simple as possible. To control simply use any standard open source Bluetooth control app on a smartphone or tablet. Easy to follow instruction booklet provided. Runs from 18650 rechargeable lithium cells (Z 6452 requires 2pcs). **Ages 8+**

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SIGNS DON'T WORK!

YOU NEED THIS JUNK MAIL REPELLER!

Is your letterbox full of junk, even though you have a NO JUNK MAIL sign? If so, you need to build our Junk Mail Repeller. It might not completely prevent junk mail from being shoved in your box. . . but it should at least help. And you'll have some fun watching the reactions of the would-be junkmeister!

by Allan Linton-Smith

Let's face it, the people who deliver junk mail must be completely blind (or no comprehende Engrish!) because they can't seem to understand the "NO JUNK MAIL" or "NO ADVERTISING MATERIAL" sign in giant letters on your letterbox.

But hopefully they aren't deaf, too; that's where this gadget comes in. For a little over two dollars (plus a few bits and pieces that you probably already have), you can build this junk mail-triggered digital audio recorder/playback device.

Just imagine, as they cram yet another flyer into your letterbox, a voice yells back at them: "**HEY YOU! The sign says NO JUNK MAIL!**"

That's just one of its many uses! But fundamentally, it's just a fun project that you could probably think of a thousand uses for.

Maybe a switch on your bedroom door and a voice saying *"sisters not welcome!"*?

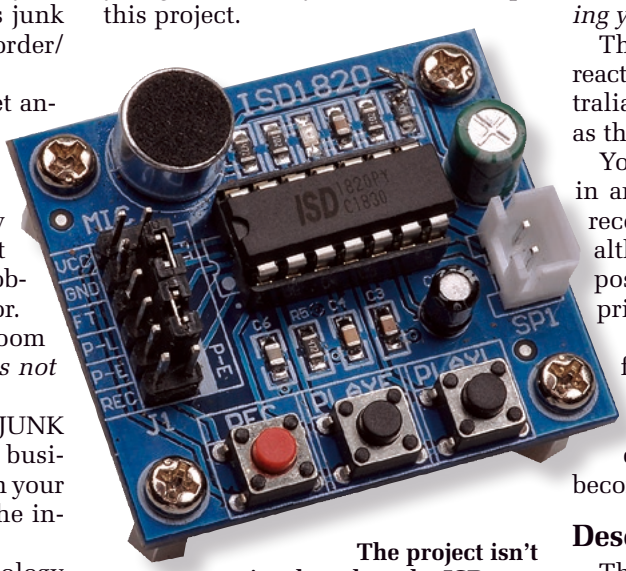
By the way, even with a "NO JUNK MAIL" sign, it isn't illegal for a business or individual to put a flyer in your letterbox (even if it is against the industry code of practice).

The problem lies with psychology 101: the junk they're delivering to you isn't junk – it's a vital message that you would be most upset not to receive.

Therefore any sign doesn't apply to them. Only to the next bloke with *junk*!

So people who stuff junk mail in your box can't be arrested! But you can discourage (and probably annoy) them with this device.

If you actually like and want junk mail (and that is about the only mail you get these days), do not attempt this project.



The project isn't just based on the ISD1820 module . . . it IS the project!

Or maybe you *should* build it and use it to say "thank you" to the people delivering you free catalogs.

How does it work?

Every time a flyer or catalog goes into your letterbox, the extra weight should be enough to trigger a microswitch – and they're greeted with a message – eg, *"No junk mail please – Australia Post only.....we are watching you!"*

Then have some fun watching their reactions! (Tough luck if it is your Australia Post postie delivering the junk, as they sometimes do!).

You can put any message you like, in any language. We discourage the recording of a tirade of swear words, although that would of course but possible, as it may land on inappropriate ears.

There isn't much to it; it's made from a pre-built, low-cost digital voice recorder which is installed in a plastic box, along with a microswitch and a battery. It then becomes a junk mail repeller!

Description

The voice recorder/playback module we're using is based on an ISD1820

We built our Junk Mail Repeller into a UB3 Jiffy box but just about any enclosure will do, as long as it fits inside your letterbox. The microswitch glued to the outside of the lid is the secret: it triggers the voice message whenever anything heavier-than-an-envelope (eg, junk mail!) lands on it. The switch on the end is optional – it changes the length (and quality) of the voice recording which YOU make to suit the situation.

IC, which can record up to 11 seconds of audio.

We chose this one because (a) it's a nice, small unit, measuring just 38 x 42.5mm; but (b) more importantly, it's cheap and really easy to get; you can get it from our online shop (see the parts list for details) or you can wait a few weeks after ordering from eBay or AliExpress, etc. Search for "isd1820".

We'd suggest being just a little careful on line – the best price we found was US$1.74 including postage. But another supplier was asking AU$10.58 PLUS $73.83 postage! Whew . . . we thought Ned Kelly was Australian. . .

Ours came ready-made, complete with a tiny loudspeaker. The speaker would cost you more than we paid for the whole thing if you bought it locally!

The module can be powered from 3V (its stated maximum is 7V) from two AA cells in series.

The standing current drain is 220µA, and it consumes about 38mA during playback. The cells should last for months, depending on your junk mail load!

Note that there is a slightly different module available than the one we used, which has a 10-pin header and two slide switches instead of a 12-pin header.

This one is also suitable for use in this project, but you have to make a few slight changes. These are simple enough that we'll leave them to you. That alternative module is quoted as working from 2.4-5.5V, which is fine since our battery is around 3V.

And speaking of Australian, Jaycar have a similar module which is not that much more expensive but doesn't come with a speaker. (Cat XC4605).

The circuit

The circuit of our module is shown in Fig.1. The ISD1820 (IC1) is responsible for all audio recording and playback tasks. A 100nF capacitor bypasses its 3V supply (from two AA cells).

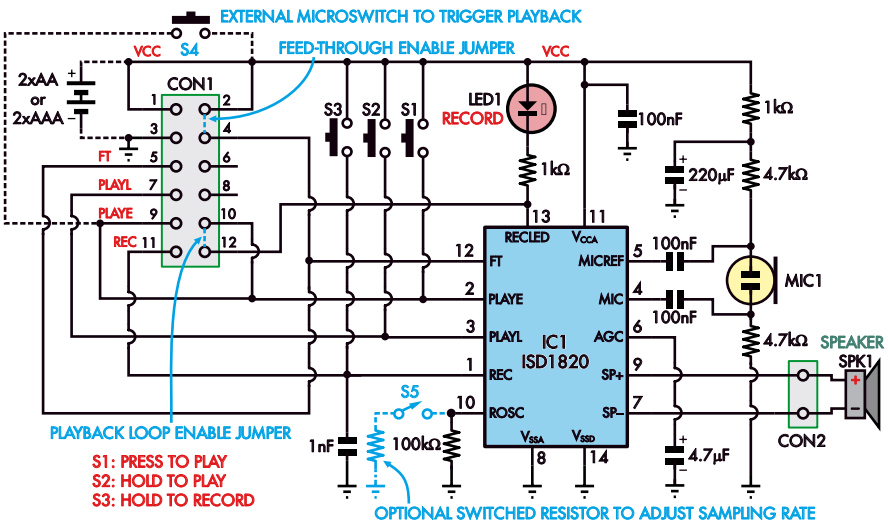
During recording, it samples audio from onboard electret microphone MIC1, which is AC-coupled to its pin 4 and 5 differential inputs. MIC1's power supply voltage is filtered by the 1kΩ resistor and 220µF capacitor, while the 4.7kΩ series resistors provide suitable biasing.

A 4.7µF capacitor sets the time constant for IC1's internal automatic gain control (AGC), used during recording to automatically provide a suitable gain for the microphone. Recording is initiated by the REC pin (pin 1) going high and continues as long as it stays high. During recording, the RECLED pin (pin 13) is held low, so LED1 lights.

The RECLED output is also pulsed low at the end of playback, causing LED1 to flash briefly.

IC1 has a small internal audio amplifier, allowing it to drive the 8Ω speaker directly, via pin header CON2. The module is supplied with a suitable cable to connect the speaker to this JST header. Playback is initiated by bringing either pin 2 (PLAYE) or pin 3 (PLAYL) high.

The difference is that the recorded message will continue to play until



SC ©2019 **JUNK MAIL REPELLER (ISD1820-BASED MODULE)**

Fig.1: the circuit of the voice recorder/playback module, with IC1 providing all of the recording and playback functions. This diagram includes the three extra components you will need, ie, a two-cell battery to power the unit, a microswitch to trigger playback of the recorded audio and optionally, a resistor connected across the onboard 100kΩ resistor to provide better sound quality.

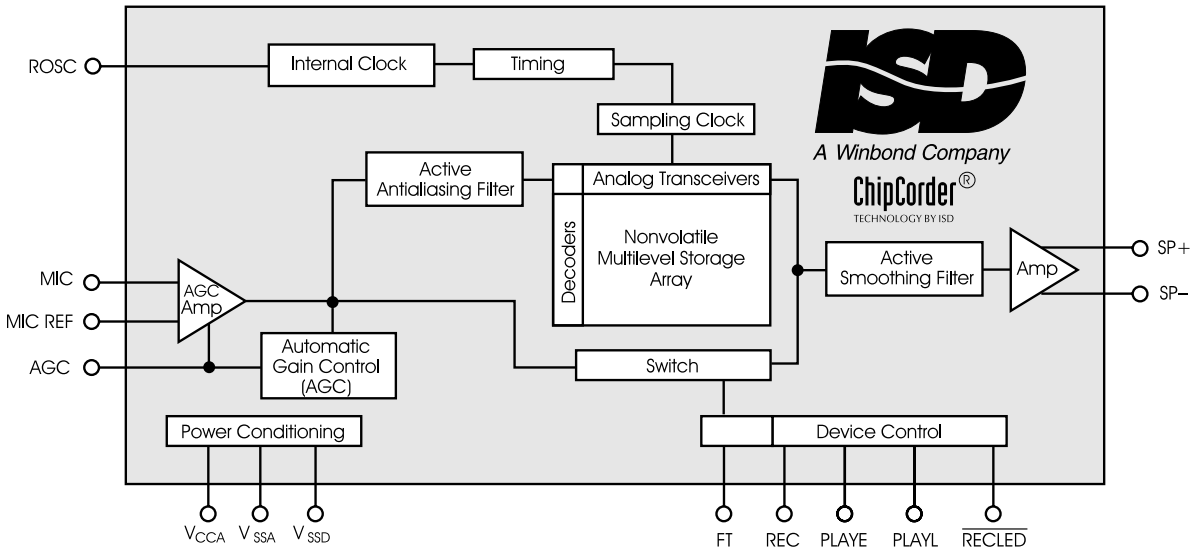


Fig.2: the internal workings of the audio recording and playback chip. The external resistor from ROSC to ground sets the oscillator frequency which determines the sampling rate. When recording is activated, the output of the microphone preamp feeds into the storage array via an antialiasing filter. And when playback is activated, the contents of the storage array are fed to the output amplifier, which is capable of driving an 8Ω speaker at a reasonable volume.

the end even if PLAYE goes low again, whereas PLAYL must be held high for playback to continue.

In other words, PLAYE is edge-triggered while PLAYL is level-triggered (hence the names). If pin 12 (FT) is held high, audio from the microphone is fed through to the output.

The module has on-board tactile pushbuttons which pull the PLAYE, PLAYL or REC pins high when they are pressed.

These signals are also fed through to pins 7, 9 and 11 of CON1 where they can be connected to external buttons, microcontroller outputs etc.

FT is fed to pin 5 of this header, while power and ground appear on pins 1 and 3 respectively.

The other half of CON1 is intended so a jumper can be placed across pins 2 & 4, permanently enabling feedthrough, or between pins 4 & 6, in which case no connection is made and feedthrough is controlled by pin 5.

Bridging pins 10 & 12 causes the RECLED output to be connected to the PLAYE input. Since RECLED is pulsed briefly low at the end of playback, after playback finishes, this will cause playback to start again, as there is a low-high transition on the PLAYE input.

Therefore, playback will loop forever, or at least until the bridging jumper is removed (it can be kept on pins 8 & 10 when not used).

Finally, the 100kΩ resistor from ROSC to ground sets the audio sampling rate to 6.4kHz, which means the maximum length of the audio recording is around 10 seconds (we measured it at 11).

This can be changed either to give a longer recording time with worse quality, or a shorter time with better quality.

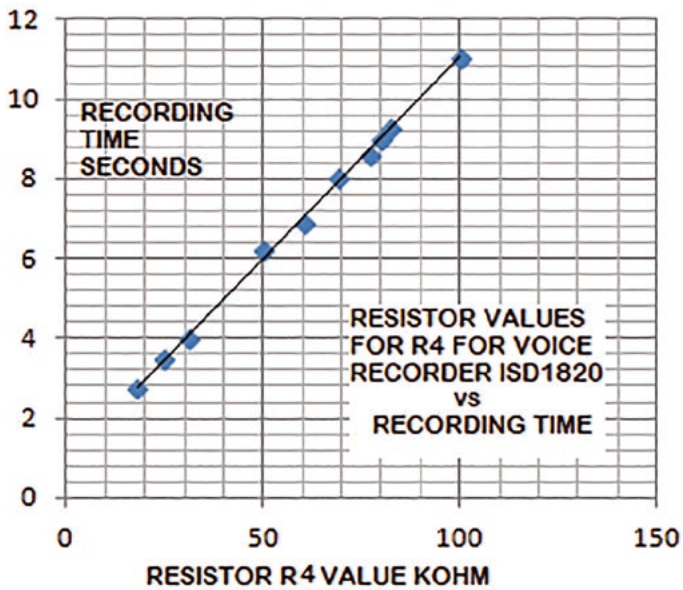


Fig.3: we varied the value of ROSC and measured the recording/playback time. As expected (based on what it says in the data sheet), the sampling rate is inversely proportional to the resistor value, thus the recording time is directly proportional to it. The sampling rate is equal to 640,000 divided by ROSC in kilohms, which gives 6.4kHz with the default value of 100kΩ.

Chip internals

Fig.2 shows the internal block diagram for the ISD1820 IC. It comprises a microphone preamplifier, oscillator, audio sample storage array, audio amplifier, filters, power conditioning and control logic.

The storage array is quoted as retaining the saved audio data for up to 100 years, or until the next time you press the REC button!

The power amplifier can deliver about 80mW into 8Ω, which is sufficient to give quite a reasonable volume when the speaker is mounted in a Jiffy box (ie, using it as a baffle).

A more powerful amplifier could be hooked up to the output, along with a larger speaker, but this may annoy your neighbours!

Recording quality vs time

We tested various values for the resistor from ROSC to ground and plotted the results in Fig.3. As you can see, it's very close to being a straight line.

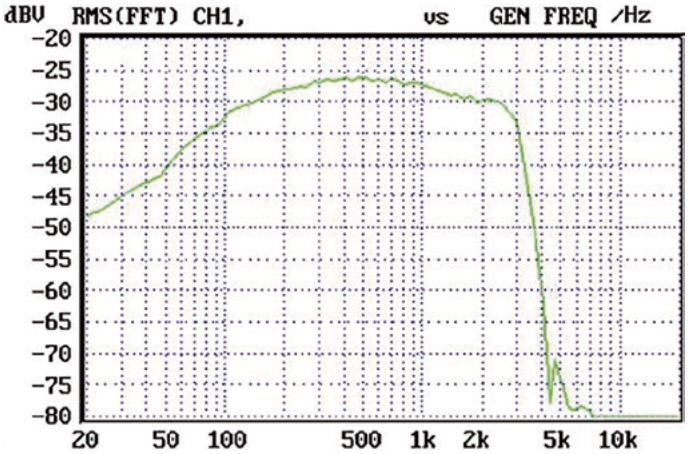


Fig.4: the measured frequency response of the unit from microphone to speaker, when the recommended 390kΩ resistor is connected across the 100kΩ onboard resistor from ROSC to ground. This gives a sampling rate of around 8kHz and an audio bandwidth of just over 3kHz. The Nyquist limit (ie, highest possible frequency) when sampling at 8kHz is 4kHz, but the filter's transition band reduces the usable bandwidth to around 3/4 of that figure. This gives eight seconds of playback time and we deem the audio quality to be adequate.

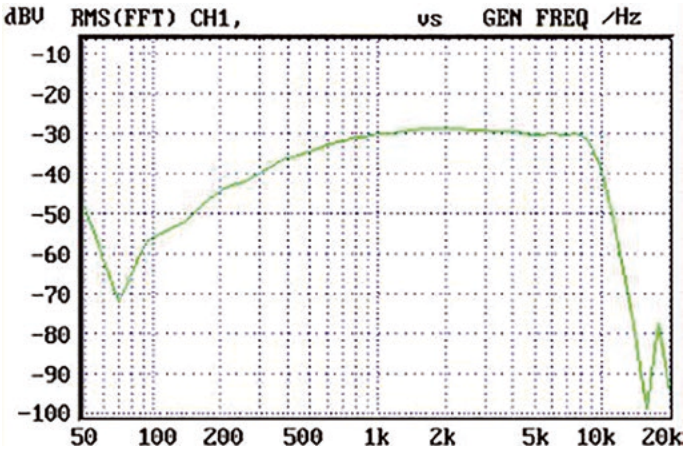


Fig.5: if you solder a 33kΩ resistor in parallel with the existing 100kΩ resistor, you get 25kΩ and that sets the sampling rate to around 20kHz, resulting in the nearly 10kHz of audio bandwidth shown here. The sound quality is better, but the playback time is now limited to around three and a half seconds. That may or may not be enough, depending on what message you intend to convey!

The minimum recommended value is 80kΩ, giving a sampling rate of 8kHz and a maximum recording time of eight seconds. But you can reduce the value down to 18kΩ, giving just under three seconds of recording time, and presumably a sampling rate of around 35kHz.

The maximum recommended value is 160kΩ, giving a sampling rate of 4kHz and a maximum playback time of 16 seconds.

You can go as high as 200kΩ, but the resulting sampling rate of 3.2kHz is poor, giving an audio bandwidth of just 1.3kHz.

While the default rate of 6.4kHz is good enough for voice, after some experimentation, we settled on 82kΩ as the best compromise, giving a sampling rate of 8kHz and around 8.5 seconds of playback time.

While the 100kΩ resistor is an SMD type, since you will probably want to lower the value if you're changing it, you can simply solder another resistor across it.

For example, connecting a 390kΩ resistor across the existing 100kΩ resistor will get you close to the 82kΩ ideal value. You can even connect this resistor via a switch, giving you two different options by merely flicking it.

Note though that if you record with the switch in one position and play back in the other, you will either sound like a chipmunk or Barry White!

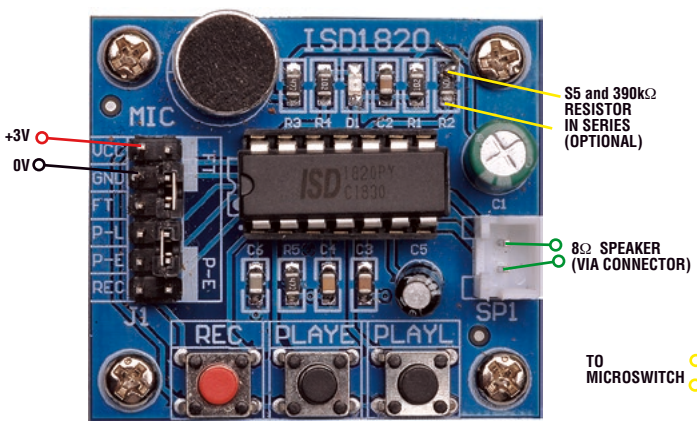
While we mounted the switch and resistor inside the Jiffy box, this may be regarded as superfluous – once you've decided on the resistor you require (if any), it could be soldered across R2 and the switch could be left out.

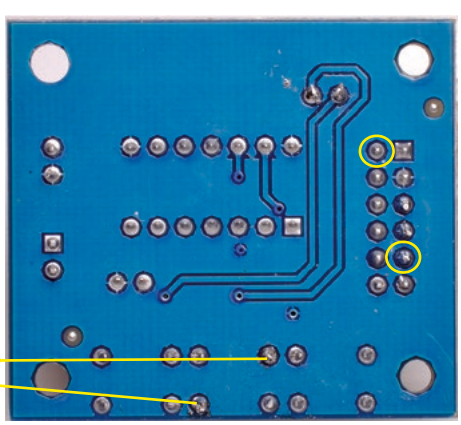
Building it

Once you have gathered the items in

PARTS LIST – JUNK MAIL REPELLER

- 1 ISD1820-based voice recorder module with a small speaker and speaker wires (Silicon Chip Online Shop Cat SC5081)
- 1 microswitch
- 1 UB3 Jiffy box (eg, Jaycar Cat HB6023 or Altronics Cat H0153)
- 1 2xAA or 2xAAA cell holder
- 1 390kΩ 1/4W 5% resistor (other values can be used; see text)
- 3 M3 x 10mm panhead machine screws, flat washers and nuts (for mounting the speaker)
- 1 SPST toggle switch (optional, for switchable sound quality)
- 2 female-female or 4 male-female jumper leads
- light-duty hookup wire
- neutral-cure silicone sealant





Front and rear shots of the PCB showing the modifications we made. The connections to the PLAYE switch on the back of the board could also be made on pads 2 and 9 of CON1 (indicated) or indeed to the pins themselves on the top side.

Three 3mm screws, with washers and nuts, hold the speaker in place, as seen here.

the parts list, building it is easy. Solder the bare ends of the supplied lead to the speaker (if they aren't already connected) and then plug this into the header on the module.

Wire up the 2x1.5V battery holder to pins 1 & 3 of CON1, with the positive end to pin 1 (don't get it the wrong way around or you might let the smoke out...)

You can do this quite easily by cutting a female-female jumper lead in half, stripping and soldering the bare ends to the battery terminals, then plugging these into CON1, taking care that the right leads go to the right pins.

You can use a similar technique to wire up the microswitch between pins 2 & 9 of CON1. Alternatively, as we did, you solder the microswitch wires to the appropriate pads on the back of the PCB (either method is fine!).

Next, drill the holes in the Jiffy box to accommodate the speaker and the microswitch. Once again, exact positioning is not needed.

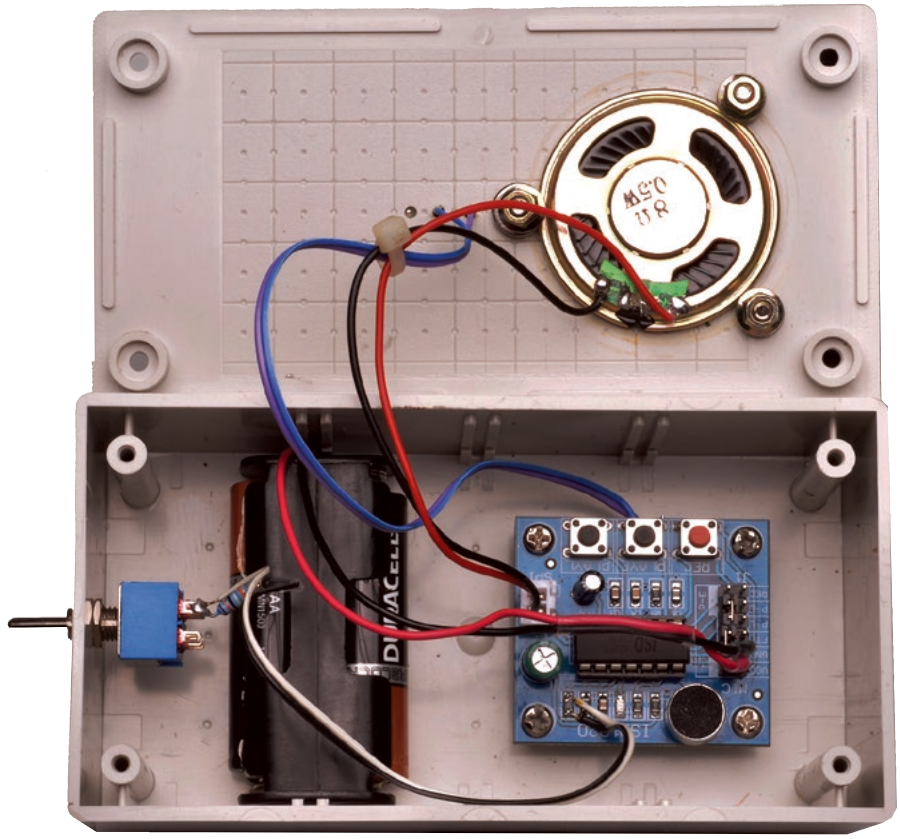
For the speaker, we cut the hole using a 35mm holesaw.The microswitch depends on which type and size you have. Ours (13 x 6mm) had three pins emerging and we drilled three 2mm holes through the lid for these pins.

You'll also want to drill three holes around the periphery of the speaker mounting hole, for machine screws to hold it into place. We drilled three 3mm holes about 3mm out from the edge of the speaker hole, 120° apart.

With these holes just outside where the speaker surround will sit, machine screws with flat washers and nuts will clamp the speaker onto the lid from the inside. See the photo above.

If using a switch to control audio quality/recording time (as we did), also drill a hole and mount this now. Put this on one side or end of the Jiffy box – you don't want it to interfere with the microswitch operation.

Depending on the type of battery holder you use, you may need to make a small clamp to hold it in position with a hole drilled in the base of the box. With the holder we used, there is no need to clamp it – it slides down between the PCB guides in the side of the case and locks nicely in place.



Here is the completed project, ready to scare off any junk mail deliverer. The AA battery holder we used is a nice friction fit in the UB3 Jiffy Box. And the switch at the end (S5) is optional – in fact, we probably wouldn't bother fitting it once we'd decided on the length and quality of our voice recording.

Check it twice!

Check that everything is working and record your message. Make sure you are happy with how it sounds, then use neutral-cure silicone sealant to seal the gaps around the edge of the speaker and microswitch holes, and any other holes you've made in the case.

While a Jiffy box is not waterproof, (especially with a speaker in the lid!) if you fit the lid on tight, it should survive the sort of splashes it's likely to be exposed to in a mailbox. If you want to be sure, you can always apply silicone around the edges of the lid before attaching it to the case.

All that's left is to place the unit in your mailbox with the microswitch facing up so that anything landing on top of it will trigger the recorded message.

Go ahead, try it out! Then hide behind a tree and wait for an unsuspecting junk peddler to wander on by...

And as we mentioned earlier, this project has plenty of other uses; eg – how about a pithy message when someone opens up your school bag?

Don't forget that most microswitches can operate in a "N-O" mode when held down and close when released – eg, when a bag is opened!

How loud is it?

On the workbench, the answer is "not very". Certainly loud enough to be really annoying – but when you place the project in your letterbox, with all its resonances, it becomes surprisingly loud.

Sure, it's not enough to scare the deliverer into a quivering mess but it should be loud enough for them to hear!

Speaking of placing it in the letterbox, make sure it is placed so that any junk mail (usually larger than legit mail!) can trigger the microswitch but ordinary mail might not have either enough weight or be in the right place to switch it. SC

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3D printing tool kit

Includes commonly required tools that you need to service your printer or to unclog a blocked print head. TD2132

NOW FROM **$19.95** ea

20% OFF

1.75mm PLA filament

The best, most consistent and most tested PLA filament engineered and manufactured by FlashForge. Various colours available.

600g TL4260 - TL4266 **WAS $24.95**
1kg TL4270 - TL4276 **WAS $39.95**

JUST **$14.95**

Rotary tool bit set

192 piece. Comes with a variety of components for sanding, engraving, cutting, grinding, and polishing. TD2455

See website for details.

NEW

NEW

JUST **$249**

ESD safe solder/desolder rework station

For professional and hobbyist use. 60W Soldering pencil and 300W rework blower. Dual digital display. Adjustable temperature. Innovative heater and sensor. Quick heat-up. TS1648

Build your own gaming station

Retro NES case

Includes access to all ports on your Raspberry Pi, additional USB ports, and a handy storage slot for your spare micro SD cards. XC4403

NEW

JUST **$39.95**

Retro NES style controller

SNES layout. Features A/B/ X/Y buttons, start, select, and direction controls. Easily configurable, USB powered. XC4404

NEW

JUST **$9.95**

JUST **$9.95** ea

Illuminated arcade buttons

Suits 25mm mounting hole. Microswitch for reliable operation. Red, yellow, green, blue & white colours available. SP0662-SP0669

JUST **$19.95**

Arcade joystick with microswitches

2 way, 4 way and 8 way options restrictor plate, metal mounting plate and main shaft, removable knob. SM1052

JUST **$19.95**

USB interface for joystick and buttons

Suitable for arcade games, flight simulators or anything that works with a USB joystick. XC9046

Tech Talk:

A soldering iron for every job

Soldering involves heating a low melting point metal alloy, mixed with flux, to fuse two other pieces of metal. Soldering finds many uses in electronics, roofing, guttering, plumbing, jewellery repair, art, and general home projects.

We have a full range of soldering tools for the amateur enthusiast through to the pro tradie. The choice of soldering iron depends on your intended application. For soldering delicate electronics components an iron with a fine tip and a stable tip temperature is generally the right tool for the job.
If you intended to do some larger jobs such as gutter repair work, then you will need an open flame blow torch or a heavy duty soldering iron with a wider tip and very high operating temperature.

We have the lot, choose your iron!

General purpose
HOBBY, ART ETC.

FROM **$13.95**

25W – 80W mains powered
- Stainless steel barrel
- Temp range: up to 380°C (TS1465) 470°C (TS1475) 530°C (TS1485)

25W TS1465 **$13.95**
40W TS1475 **$18.95**
80W TS1485 **$22.95**

DURATECH

ONLY **$26.95**

Low cost gas powered
- Adjustable tip temperature and a fold-out stand
- Great for soldering, cutting plastic, or heat shrinking plastic
- Temp range up to 450°C / 550°C hot blow / 1300°C open flame

TS1111

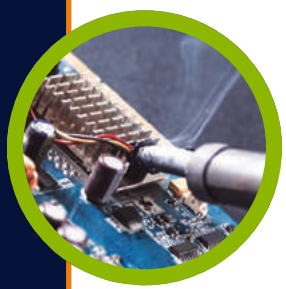
FREE BUTANE GAS NA1020

ONLY **$29.95**

3-In-1 Heat blower and soldering iron
- Flame or flameless function
- Adjustable temp control
- Piezo ignition
- Temp range up to 450°C / 500°C hot blow

TH1604

FREE BUTANE GAS NA1020



Delicate jobs
ELECTRONICS COMPONENTS

JUST **$14.95**

8W USB powered
- Long-life tip with protective cap
- Temp range up to 400°C

TS1532

JUST **$29.95**

30W mains powered
- Temperature controlled
- Plated long-life tip
- Temp range up to 450°C

TS1540

JUST **$79.95**

85W mains powered
- Exceptional heat recovery
- High insulation, low current leakage
- Electrically safety approved
- Temp range up to 320°C

TS1430

goot

Tough jobs
GUTTER REPAIR, PLUMBING ETC.

JUST **$39.95**

Piezo ignition micro torch
- Piezo ignition with safety lock
- Adjustable flame
- Temp range up to 1300°C

TS1660

FREE BUTANE GAS NA1020

portasol

NOW **$99**

SAVE $20

Super pro gas powered
- Adjustable temperature up to 580°C
- 120 min (approx.) operating time
- Internal piezo crystal ignitor
- Stainless steel finish

TS1320 **WAS $119**

portasol

NOW **$149**

SAVE $10

Super pro gas powered kit
- Built-in blow torch
- 4 tips, cleaning sponge & case included
- Quality storage case
- Temp range up to 580°C /1300°C torch temp

TS1328 **WAS $159**

Soldering accessories

ONLY **$6.95**

Solder sucker & blower bulb
Affordable, compact and effective. 110mm long.
TH1850

FROM **$9.95**

Soldering iron stands
General purpose stand. Large, tip cleaning sponge & pressed metal base.
Economy TS1502 **$9.95**
Deluxe TS1507 **$16.95**

JUST **$15.95**

Solder flux paste
Provide superior fluxing and reduce solder waste. Non-flammable, non-corrosive. 56g tub. NS3070

ONLY **$15.95 ea**

200gm Duratech solder
60% Tin / 40% Lead. Resin cored. 2 sizes available.
1.00mm NS3010
0.71mm NS3005

DURATECH

JUST **$17.95**

goot

Soldering iron tip cleaner
Static-safe, suitable for lead-free solders. Supplied with spare insert. TS1510

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your destination for

measuring temperature & more

Hand held pH meter

Simple and accurate device for checking pH levels in water. Great for keeping your fish tank at the proper pH level. 1 x 9V battery & buffer solution included.
• 1-14 pH range
• ±0.2 pH accuracy
QM1670 **WAS $64.95**
ALSO AVAILABLE:
Buffer Solution to suit QM1670
QM1671 **WAS $8.95 NOW $4.45 SAVE $4.50**

QM1671

QM1670

NOW **$59.95**

SAVE $5

NOW **$59.95**

WEATHERPROOF IP54 CASE

SAVE $10

Mini laser distance meter

Measure distance up to 20m with an accurancy of just 1.5mm!
• Works in metric or imperial measurements
• Area and volume calculations
QM1626 **WAS $69.95**

ONLY **$59.95**

Digital lightmeter

Measure light in 4 ranges (from 0.01 to 50,000 lux).
• 3.5 Digit LCD display
• 1 x A23 battery included
• Separate photo detector
QM1587

NOW **$79.95**

SAVE $20

Solar power meter

Optimises solar panel installations by finding optimum locations for the panels. Expressed as Watts per square metre (W/m²), or British thermal units per square foot (BTU/ft²). Includes carry case and 3 x AAA batteries.
• 0-1999W/m², 634BTU/ft² range
QM1582 **WAS $99.95**

NOW **$49.95**

SAVE $10

3-in-1 Stud detector with laser level

Laser levelling, layout and stud locating on vertical and horizontal surfaces.
• 1 x 9V battery included
QP2288 **WAS $59.95**

NOW **$24.95**

SAVE $10

Pocket moisture meter

Measure water content in building materials and wooden fibre articles. Auto power off. Backlit digital LCD screen.
• 4 x LR44 batteries included
QP2310 **WAS $34.95**

ONLY **$24.95**

CAT III Non-contact AC voltage detector

Detects AC voltages from 50 to 1000V.
• LED flashlight function
• 2 x AAA batteries included
QP2268

• BACKLIT LCD
• FOLDOUT STAND

True RMS autoranging DMM with temperature

Powerful, Cat III 600V digital multimeter. Features non-contact voltage testing, continuity, diode check.
QM1551 **WAS $64.95**

NOW **$59.95**

SAVE $5

Non-contact thermometers

Safely measure temperature in hard to reach places, hot or hazardous areas. Backlit LCD. Built-in laser pointer.

NOW **$49.95**

SAVE $10

8:1 Spot

• Economy
• 3 Digit display
• Temp range: -30°C to 260°C
• 131mm long
QM7215 **WAS $59.95**

NOW **$119**

SAVE $20

12:1 Spot

• Dual laser targeting
• 3.5 Digit Display
• Temp range: -50°C to +650°C
• 146mm long
QM7221 **WAS $139**

NOW **$219**

SAVE $30

30:1 Spot

• Professional high temperature
• 4.5 Digit display
• Temp range: -50°C to 1000°C
• 230mm long
QM7226 **WAS $249**

Tech Talk: Distance to spot ratio explained

Distance to spot ratio is the ratio of the distance of the thermometer to the object being measured, and the diameter of the temperature measurement area. The larger the ratio number the better the resolution.

STAINLESS STEEL

ONLY **$29.95**

Digital stem thermometer

Multi-purpose thermometer for lab, factory workshop or barbeque. Features fast response, min/max memory and data hold. 205mm long. LR44 battery included. QM7216

ONLY **$24.95**

Digital thermometer for fridge or freezer

Keep your fridge at the right temperature all year round. Shows room temperature at the touch of a button. Temp range -50 to 70°C. QM7209

QP6013

FROM **$99**

SAVE $20

USB temperature & humidity dataloggers

Log temperature and humidity readings and store them in internal memory for later download to a PC.
Plug-In Type QP6013
WAS $119 NOW $99 SAVE $20
USB/LCD Readout Type QP6014
WAS $149 NOW $129 SAVE $20

NOW **$29.95**

SAVE $10

Digital thermometer with K-type thermocouple

Excellent measurement range from -50°C - 750°C and a hold function to lock the reading on the display. Thermocouple included. 3.5 digit LCD.
• 1 x 9V battery included
QM1602 **WAS $39.95**

your destination for projects & DIY.

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PROJECT: ultrasonic radar

Watch a cool radar slide across your computer screen like the old war-time movies! Using the simple ultrasonic sensor to measure distance in a rotating fashion across your workbench.

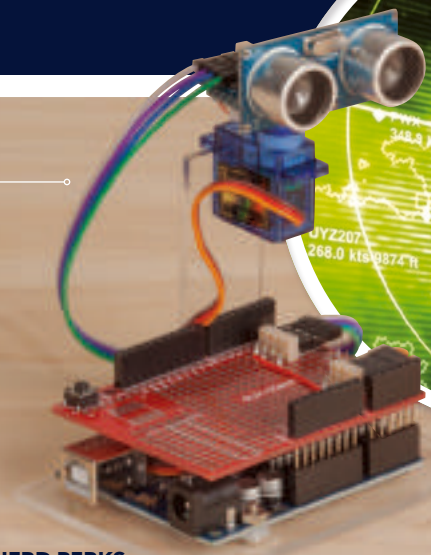
Uses Arduino and the easy-to-use "Processing" for GUI programming on your computer.

Note: Accuracy of detecting helicopters not guaranteed.

SKILL LEVEL: Beginner
TOOLS: Drill, Soldering Iron

SEE STEP-BY-STEP INSTRUCTIONS AT:
www.jaycar.com.au/ultrasonic-radar

1 x Duinotech UNO r3 Development Board	XC4410	**$29.95**
1 x Prototyping Board Shield	XC4482	**$15.95**
1 x 9G Micro Servo Motor	YM2758	**$9.95**
1 x Dual Ultrasonic Sensor Module	XC4442	**$7.95**
1 x Socket to Socket Jumper Leads - 40pce	WC6026	**$5.95**
1 x Prototyping Shield for Wi-Fi Mini	XC3850	**$4.95**
2 x 4 Pin 0.1" Locking Header	HM3424	**40¢ ea.**
1 x 3 Pin 0.1" Locking Header	HM3423	**35¢**



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$39.95

SAVE 45%

KIT VALUED AT $75.85

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LUCAS
from Kew East, Victoria for sharing his brilliant project idea!

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Check out our huge range of Arduino compatible development boards from basic to the most advanced Wi-Fi and Bluetooth connected projects. It's all here at a FANTASTIC PRICE!

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Indicates that the product will work in your Arduino® based project.

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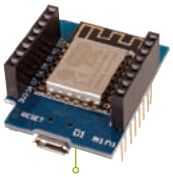
ESP32 main board

Dual core microcontroller equipped with Wi-Fi and Bluetooth connectivity. 512kB of RAM, 4MB of flash memory and heaps of IO pins. XC3800

ONLY **$24.95**

Wi-Fi mini ESP8266 main board

Perfect compact solution to your IoT sensor node problem. Packs an 80MHz microcontroller with Wi-Fi into a board. 4MB flash memory. 11 digital IO pins. XC3802



ONLY **$59.95** WITH WI-FI

Mega with Wi-Fi board

Includes a traditional Arduino MEGA chip + layout as well as an ESP8266 chip to connect your projects to the cloud. XC4421

Uno with Wi-Fi board

NEW

Similar to UNO but with the addition of Wi-Fi for amazing IoT projects. XC4411

JUST **$14.95**

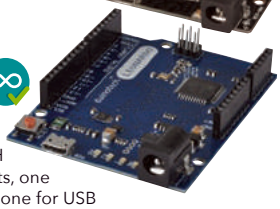
Lilypad board

Compact ATMega 32U4 based main board. A single chip handles main controller functions as well as USB connectivity. 9 Digital IO pins.
• LiPo Battery charging connector and circuitry
XC4620

JUST **$29.95**

Leonardo

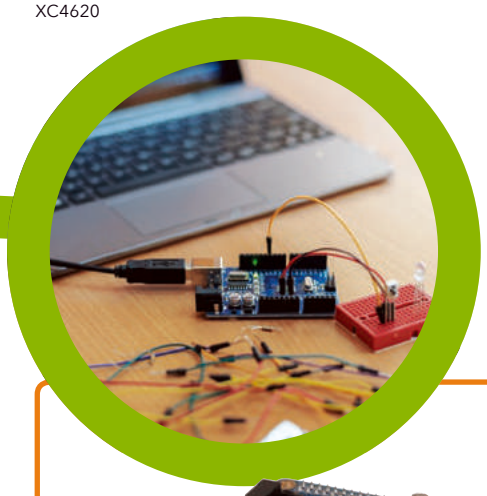
Most of the DuinoTECH models use two chipsets, one for the main controller, one for USB communication. Now you can have your DuinoTECH Lite emulate a computer keyboard, mouse, joystick and many other types of input device. XC4430



JUST **$29.95**

Duinotech nano board

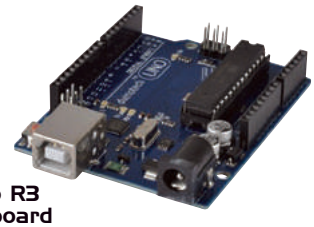
Small in size, but packs virtually all the features of the full duinotech boards into a tiny DIP-style board that drops directly into your breadboard.
• ATMega328P microcontroller
XC4414



JUST **$29.95**

Duinotech uno R3 development board

100% Arduino® compatible. Stackable design makes adding expansion shields at ease. Powered from 7-12VDC or from your computers USB port. ATMega16u2 USB-Serial chipset. XC4410



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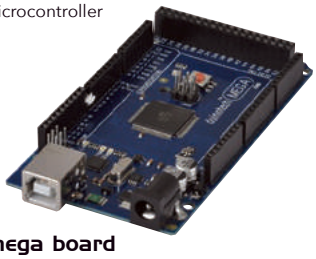
DuinoTECH mega board

Our most powerful Arduino® compatible board. Boasting more IO pins, more memory, more PWM outputs, more analogue inputs and more serial ports. 256kb program memory. ATMega2560 Microcontroller. XC4420



what's new

ONLY **$69.95**

Digital audio converter

Used this module to create your own Raspberry Pi based music player or just improve the sound quality from your Raspberry Pi. XC9048

ONLY **$29.95**

Dual card adaptor

Insert the SD card switch into your Raspberry Pi to switch between operating systems on separate microSD cards. No power required! XC9034

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Lithium-ion battery power pack

Make your Raspberry Pi project completely portable with this power expansion board. Attaches directly to Raspberry Pi. 2 x USB output ports. XC9060

FROM **$4.95**

Clear acrylic enclosures for Arduino®

Protect your Arduino board against damage, dust and scratches. Pre-drilled to provide easy access to all ports.
Suits Uno XC4406 **$4.95**
Suits Mega XC4408 **$6.95**

JUST **$7.95**

Smoke detector module

Detects butane, propane, methane, alcohol, hydrogen, and smoke. XC4470

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Add vision to your next Raspberry Pi project using our high quality 5MP camera. Dual infrared LEDs. Performs even in dim environments. XC9021

JUST **$49.95**

3.5" Touchscreen LCD with stylus and enclosure

Perfect for prototyping or to set up a portable device with your Raspberry Pi 3B+. Minimal set-up. XC4631

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Inspection camera with 3.5" detachable wireless LCD
View and record video and pictures in confined and dark locations. 1m flexible boom.
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50W Curie heat technology soldering station
TS1584 **REG $379**

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Servisol sprays & aerosols
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NERD PERKS SAVE **25%**

Resistor pack
0.5W 1% mini size metal film. 300pcs.
RR0680 **REG $16.95 CLUB $11.95**

NERD PERKS SAVE **10%**

Rotary tool kit
Drill, saw, sand, polish, carve or grind. 210pce. TD2459
REG $54.95 CLUB $48.95

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Dual PC monitor desk stand
Accommodate two monitors up to 27" each. CW2880 **REG $99.95 CLUB $79.95**

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Alarm cable
4 core. 30m roll.
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Visor mount rechargeable Bluetooth handsfree system
Connects two phones simultaneously.
AR3138 **REG $69.95 CLUB $49.95**

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16 piece. WT5218
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2pin mains plug to IEC C7 female
SAA approved. 5m.
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Corrosion buster pen
Remove rust, wax and dirt.
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Mini gas soldering tool set
Piezo ignition, temperature adjust.
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70A circuit breaker
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Power point and earth leakage tester
Multiple testing options.
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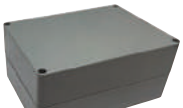

IP65 sealed ABS enclosure
Large 171 x121 x 80mm.
HB6129 **REG $21.95 CLUB $14.95**

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COMPONENT STORAGE CASES*
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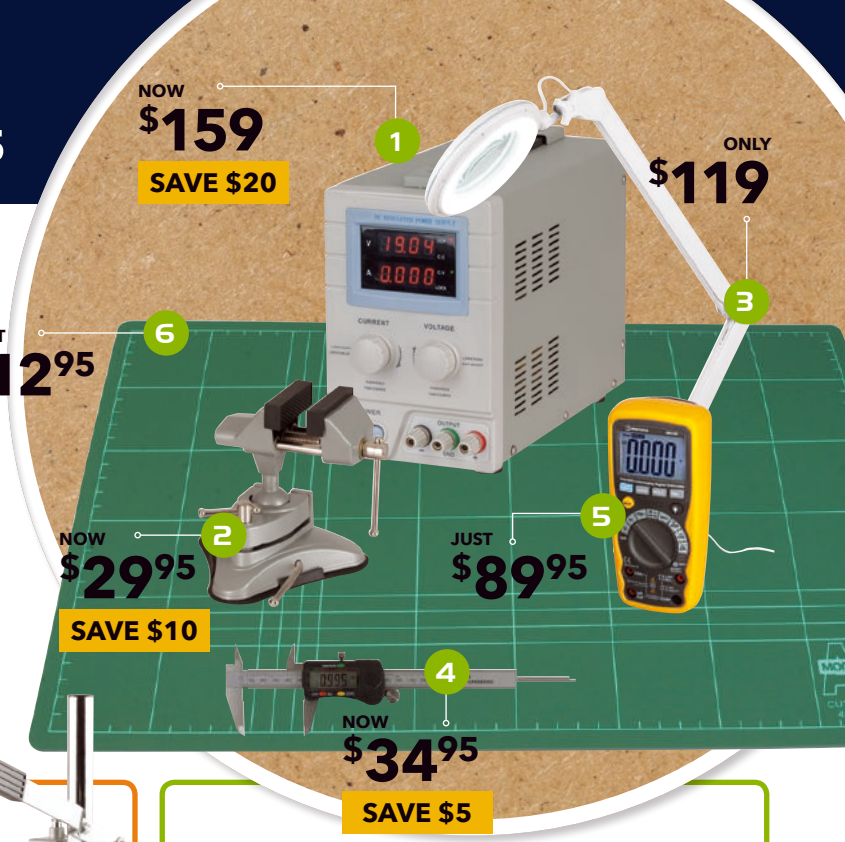

1. 0-30VDC 0-5A regulated lab power supply
- Digital control, large LED display
- Built-in over-current & short circuit protection
- Output current: 0-5A
- 270(L) x 120(W) x 185(H)mm

MP3840 **WAS $179**

2. Bench vice
- Made from hard-wearing diecast aluminium
- Vacuum base and ball joint clamp
- 75mm opening jaw
- 160mm tall (approx)

TH1766 **WAS $39.95**

3. LED illuminated clamp mount magnifier
- 125mm diameter 3 dioptre lens
- High / low light setting
- Fully adjustable arm with clamp mount
- Large diameter magnifier
- Interchangeable lens option

QM3554

4. Digital vernier caliper
- Stainless steel. 5-digit LCD
- 0 - 150mm (0-6") range
- Resolution 0.01mm / 0.0005 (repeatability same)
- Thumbscrew slide damper
- LR-44 battery supplied

TD2082 **WAS $39.95**

5. CAT IV True RMS autoranging DMM
- Large, easily to read display
- IP67 environmental rating
- 600V, 4000 count
- AC/DC voltages up to 1000V
- AC/DC currents up to 10A

QM1549

6. Benchtop work mat
- Cut, solder, write on it and not damage your workplace
- Durable A3 size PVC
- 450 x 300m

HM8100

JUST $17.95

3 SMALL DRILL BITS IN TUBULAR CASE

Spiral drive drill/driver
- 2 pin vice collets: 0.3-1.0mm & 1.8-2.6mm

TD2089

JUST $13.50

Pin vice
Metal construction with two internal collars. TH1772

JUST $13.95

4-pce countersink set
Bits include 12, 16 and 19mm. TD2027

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SAVE $5

Universal drill press stand
Convert your standard power drill or rotary tool into a drill press with this adjustable stand. Heavy duty cast metal base and frame.

TD2463 **WAS $39.95**

VDE approved insulated tools

7-pce screwdriver set
Fully insulated screwdriver set for electrical work.
- Slotted sizes 2.5mm, 4mm, 5.5mm & 6.5mm
- Phillips sizes #0, #1, and #2
- 1kV insulation rating

TD2022

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8-pce screwdriver & tool set
Features quality rubber-moulded insulation for in-hand comfort.
- VDE approved to 1000V
- Insulated right to the tip

TD2031 **WAS $59.95**

TH1984

NOW $17.95 ea

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Insulated pliers & cutters
Strong, tough and reliable. Can cut piano wire up to 1.6mm. Comfortable double inset handles. GS approved. **WAS $24.95**

7" 180mm Bull Nose Pliers	TH1984
6" 160mm Side Cutters	TH1985
6.5" 170mm Long Nose Pliers	TH1986

These SOLDERING STATIONS provide accurate and controllable tip-temperature, with a high degree of accuracy and precision, for faster heat transfer and best tip-temperature recovery during heavy usage.

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SAVE $10

48W
- Adjustable temperature (150-450°C)
- Ceramic element and lightweight pencil
- Analogue display
- 150(L) x 115(W) x 92(H)mm

TS1564 **WAS $99.95**

NOW $129

SAVE $20

60W ESD safe
- Adjustable temperature (160-450°C)
- High temperature stability
- LED display
- 160(L) x 104(W) x 124(D)mm

TS1640 **WAS $149**

NOW $249

SAVE $50

65W ESD safe
- Adjustable temperature (200-480°C)
- Excellent temperature stability and anti-static characteristics
- LED display
- 146(L) x 115(W) x 98(H)mm

TS1440 **WAS $299**

clearance

save up to $40

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SAVE $40

12V 10A intelligent 5-stage battery charger
For charging and maintenance. Safe to leave connected for months at a time.
- Short circuit protection
- Voltage compensation
- Overheat protection

In-store only. MB3625 **WAS $139**

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$49.95
SAVE $20

3.5" Head-up display with GPS
- Built-in GPS & compass
- Over speed alarm
- Auto brightness adjustment
- 12/24VDC operation

LA9032 **WAS $69.95**

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$34.95
SAVE $20

Alcohol breath tester
Quickly and easily check your blood alcohol content. Backlit LCD. 3 x AAA batteries required.
Note: Readings are for reference only, we hold no responsibility for the use of these devices. QM7304 **WAS $54.95**

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$59.95
SAVE $30

Mini wireless alarm kit
- Quick and easy installation
- Easily expanded to cover a greater area
- Super-loud 120dB siren

LA5282 **WAS $89.95**

QC3837

QC3841

NOW
$64ea
SAVE UP TO $20.95

Wi-Fi IP cameras
Wi-Fi connectivity makes installation a breeze.
720p with Pan/Tilt/Zoom QC3837
WAS $79 NOW $64 SAVE $15
720p with Infrared LEDs QC3841
WAS $84.95 NOW $64 SAVE $20.95

NOW
$119

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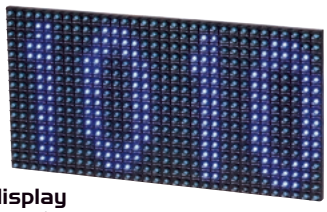

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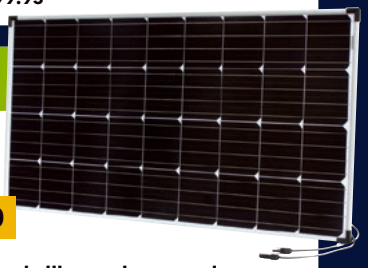

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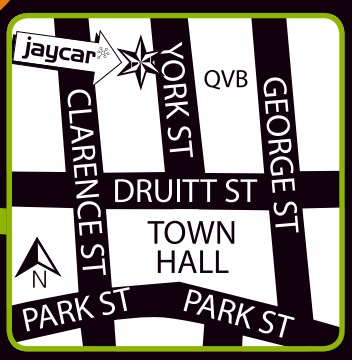

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PRODUCT SHOWCASE

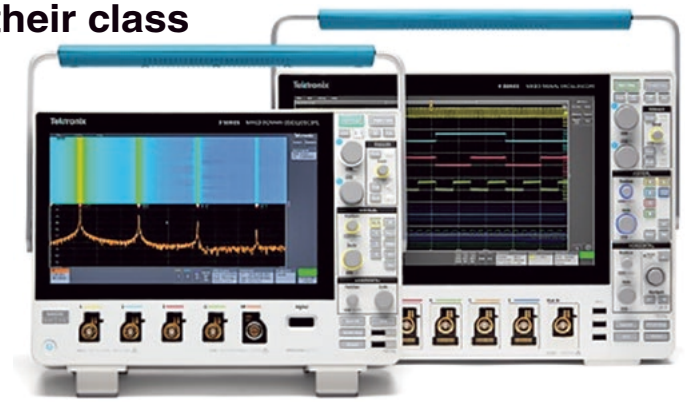
Largest high-definition 'scopes in their class

The new 4-Series MSO and 3-Series MDO oscilloscopes from Tektronix offer more display, more signals, more resolution and advanced capabilities. Both have the largest capacitive touch screens in their class.

The 200MHz-1.5GHz 4-Series Mixed Signal Oscilloscope has a 33.75cm HD (1920 x 1080) capacitive touch display with up to six analog and digital FlexChannel inputs with 12-bit vertical resolution; up to 16 bits in Hi Res models. There is support for more than 20 serial bus protocols and the 4-Series also offers an optional inbuilt function generator.

The 100MHz-1GHz 3-Series Mixed Domain Oscilloscopes have a 29.5cm HD (1920 x 1080) capacitive touch screen, either two or four channels, a built-in spectrum analyser (on the 1GHz and 3GHz models) and an optional built-in function generator.

They support a wide range of serial bus decoding and triggering options.



For more information on the 4-Series and 3-Series 'scopes from Tektronix, visit the Vicom Australia website.

Contact:
Vicom Australia Pty Ltd
1064 Centre Rd, Oakleigh Sth, Vic 3167
Tel: 1300 360251
Web: www.vicom.com.au

Integrated Passive Components simplify signal conditioning in package that is 20% the size

Integrated Passive Components (IPCs) are attracting increasing interest due to the miniaturisation of wireless devices, as well as the need to increase reliability of signal conditioning in RF circuits such as filtering, impedance matching, differential to single ended conversion and coupling.

IPCs are essentially electronic sub-systems that combine multiple discrete passive components into a single surface mounted device. Low Temperature Cofired Ceramic (LTCC) technology allows the passive components to be layered "3-dimensionally." IPCs deliver the same functionality as 10-40 individual components.

With this approach, the entire front-end between the RF chipset and the antenna can be manufactured in a single, ultra-low profile (0.35-1.0mm total thickness) package that is less than 20% the total size of the same circuit comprised of discrete components.

Using this manufacturing process, Johanson Technology has developed a line of small, highly reliable IPCs for RF systems.

These components operate over several bands from 300MHz to 10GHz covering Cellular, DECT, WLAN, Bluetooth, 802.11 (a, b and g) and GPS applications.

IPCs are available for almost any type of passive circuit, including low and high-pass filters, diplexers, triplexers, impedance matched baluns, balun-filters, band pass filters, couplers and other custom signal conditioning circuits.

Contact:
Johanson Technology
4001 Calle Tecate, Camarillo, CA 93012, USA. **Tel:** (0011) 1 805 389 1166
Web: www.johansontechnology.com

Microchip's new ECE1200: the first commercial eSPI-to-LPC Bridge

Microchip Technology has introduced the industry's first commercially available eSPI to LPC bridge. The ECE1200 bridge enables developers to implement the eSPI standard in boards with legacy LPC connectors and peripherals, substantially minimising development costs and risk.

The ECE1200 eSPI to LPC bridge allows developers to maintain long lifecycles while supporting the eSPI bus technology that is required for new computing applications. To reduce risk for developers, the eSPI bus technology went through intensive validation for industrial computing applications and has been validated with leading processor companies.

Designed for today's eSPI requirements, the ECE1200 detects and supports Modern Standby mode with low standby current.

Contact:
Microchip Technology Inc
U32, 41 Rawson St, Epping NSW 2121
Tel: (02) 9868 6733
Web: www.microchip.com

ElectroneX '19 returns to Melbourne with new venue

ElectroneX – The Electronics Design & Assembly Expo and Conference – returns to Melbourne this year on 11-12 September.

However, the venue has changed: it will be in the Melbourne Conference and Exhibition Centre (MCEC). The show is on track for a sellout with more exhibitors and products than ever before.

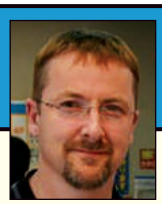
First held in 2010, ElectroneX has grown to become the pre-eminent exhibition for companies using electronics in design, manufacturing and assembly in Australia

The SMCBA Surface Mount Conference is also held concurrently with the Expo, with a range of workshops for engineers, designers and manufacturers. A comprehensive Design Workshop will also be held.

Contact:
Aust. Exhibitions & Events Pty Ltd
PO Box 5269, Sth Melbourne Vic 3205
Tel: (03) 9646 9533
Web: www.electronex.com.au

SERVICEMAN'S LOG

Remaking a 'vintage' guitar FX pedal



Dave Thompson

Ask any guitar player (or just hang around one for a couple of minutes), and they'll soon tell you everything about their 'sound' and the lengths they've gone to in order to achieve it. But for many of us, finding our tone can be frustrating.

Most beginners (a group in which I include myself) start by wanting to emulate an existing player's sound and style, with the likes of Buddy Holly, Jimi Hendrix, Hank Marvin, Eric Clapton and Eddie Van Halen all being popular role models back in my day. Of course, the sound I want my own guitar(s) to make is influenced by the musical direction I want to go in.

I recall trading a skateboard for my first electric guitar; the last in a long line of musical instruments I'd tried my hand at as a schoolboy. While proudly showing it off to another friend, he asked a question I had no answer for at the time: "Why doesn't it sound like guitars on all the records we listen to?"

At that stage, I hadn't even considered what I wanted to sound like; all I knew at the age of 16 is that I'd likely be far more popular with girls as a guitarist rather than a clarinettist! (As it turned out, it made no difference…)

My quest to answer that question plunged me into the world of guitar amplifiers, speakers and effects pedals.

It was typical of me to think of hardware before even learning to play! In my defence, all the glossy magazines and peer pressure at the time emphasised having the 'right' gear rather than actual playing, so I can blame at least some of that for my early decisions (how's that for a rationalisation?).

Another school chum said he had an old valve amplifier I could have if I wanted it. At the time, my hobbyist electronics experience had been limited to relatively simple transistor-based projects gleaned from 1970s electronics mags, so the world of valves was alien to me. I was soon to learn that this mono 'hifi' type amplifier, salvaged from an old radiogram, wouldn't be any good as a guitar amp anyway.

What I really wanted was something with a bit of gain and bite to emulate the popular lead guitarists' tone of the time; with mismatched input impedances and lack of a high-gain stage, without significant mods (far above my pay-grade at the time), this amp wouldn't be much chop at all.

At least I could now hear what I was trying to play, though the ancient speaker burgled from the same wrecked radiogram was about as suitable for guitar reproduction as the amp itself. But it was loud enough to elicit the ubiquitous "turn that thing down!" command from my parents that all aspiring guitar players will be familiar with.

My usual retort was that they should be glad that I didn't want to learn to play the drums!

An expensive hobby

This process gave me my first taste of being what is now colourfully

GUITARMAN'S LOG
Jimi Thompson
MOST BEGINNERS (ME INCLUDED) START BY EMULATING AN EXISTING PLAYER'S SOUND & STYLE...
ON
OFF
ALL I KNEW AT 16 WAS THAT I'D BE FAR MORE POPULAR WITH GIRLS AS A GUITARIST RATHER THAN A CLARINETTIST
~AS IT TURNED OUT, IT MADE NO DIFFERENCE

Items Covered This Month

- Pedal to the heavy metal
- An 1890s Weston voltmeter repair
- Idle-stop-start-system fault
- Fisher & Paykel "French door" fridge repair

Dave Thompson runs PC Anytime in Christchurch, NZ.

Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

called a 'gear slut'. It is a natural human tendency to try to overcome a perceived deficiency by throwing money or resources at it, and I am no exception.

However, the more I learned, the more I discovered that anything worth having in the guitar-playing business cost a lot more than the average pimply teenager could scrape together.

While it's true that buying a top-quality brand-name guitar is as prohibitive today as it was then, I'd still have needed to work my after-school job for years to be able to afford something like a Fender Stratocaster or a Gibson Les Paul, arguably the two most sought-after models in history.

I ended up with a reasonably good Strat clone, but still had to plug it into a proper amp to get any real sound out of it. At the time, transistor amps were very much in-vogue and becoming far more affordable than tube amps, due to the proliferation of increasingly-inexpensive and ever higher-powered transistors and hybrid amplifier modules.

This, coupled with a concerted campaign by the marketing people to portray valve amps as being old-fashioned, heavy to cart around, expensive to repair and all but superseded by the miracles of modern electronics, led to a boom in solid-state amplifier sales.

The ever-diminishing stocks and increasing cost of suitable valves and transformers also made going solid-state appear to be the sensible option. However, more-savvy guitar players knew the truth; transistors didn't sound as good as valves when used in guitar amplifiers.

Making transistor guitar amps sound better

To combat this, manufacturers of solid-state amps soon started using a variety of circuits to try to emulate the much-desired 'valve sound'. This sparked another sales boom, this time in effects pedals.

Ironically, many of these floor-mounted units were solid-state, yet all manner of electronic jiggery-pokery was used to try to capture the 'warm', harmonic-rich and more pleasant-sounding distortion that valves naturally exhibit when pushed outside their normal operating parameters.

These days, sophisticated solid-state 'modelling' amplifiers that can make any guitar sound fantastic are highly regarded (and very expensive!) but in general, transistor guitar amps are thought of as sounding 'harsh' and discordant when over-driven.

While not ideal for certain guitar sounds, transistor-based amps have found favour for those desiring lower-gain but still-powerful 'clean' sounds, such as in country or jazz music and for keyboard or bass guitar amplification (although many bass players do like to add a little 'fuzz' too!).

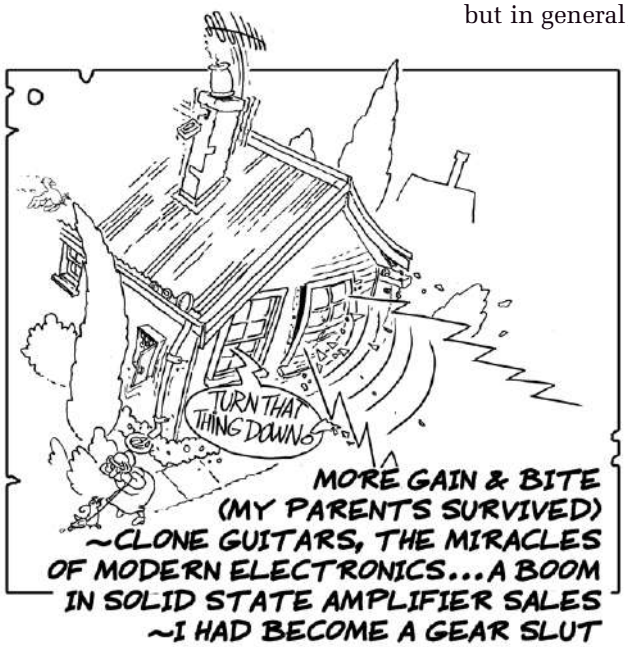
One of the earliest attempts at making any amplifier sound better is a device called a "Tone Booster", or "Treble Booster". This is essentially a low-gain preamp and filter that was intended to add some extra sparkle to an overdriven valve amplifier, due to the tendency of the sound to 'darken' when the amp was pushed into clipping.

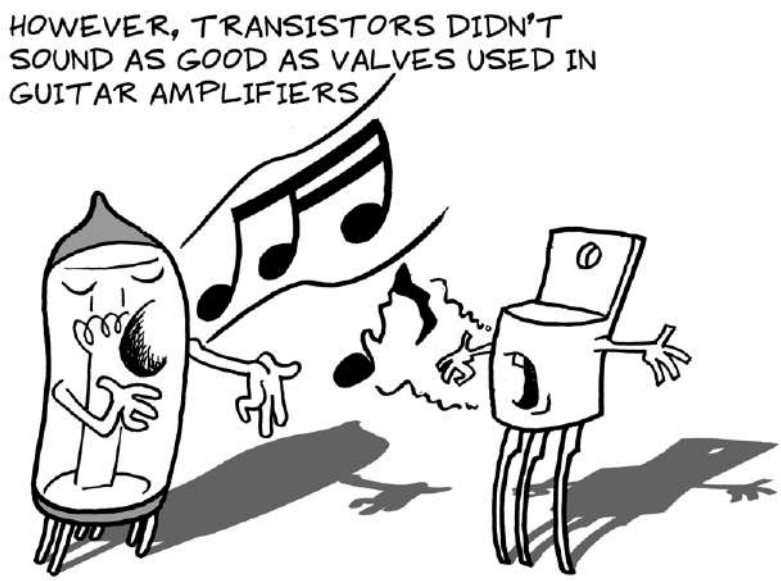
They typically also boosted the output of then-weaker guitar pickups, which added a hint of overdrive and colour to the sound.

Many different companies made these units, some of which are now prized and highly collectible. There were also local companies and savvy individuals making clones of these boosters, hoping to cash in on the popularity and scarcity of overseas models.

My assignment, which I chose to accept

This brings me to my current assignment; a customer called at the workshop bearing one such Tone Booster clone and wanted it refurbished so that he could use it. He'd acquired it from someone's estate, and it appeared to have been sitting in a garden shed for the last 50 years.


TURN THAT THING DOWN!
MORE GAIN & BITE (MY PARENTS SURVIVED) ~CLONE GUITARS, THE MIRACLES OF MODERN ELECTRONICS...A BOOM IN SOLID STATE AMPLIFIER SALES ~I HAD BECOME A GEAR SLUT



There was no name on the now-shabby and rust-spotted metal case, and the faded panel labels had been simply-but-neatly drawn on. But it was quite well-made with tidy, point-to-point wiring evident among the cobwebs and dead earwigs inside.

It was anybody's guess who'd made it, or when, but with a battery attached, it still worked, though the pot was shot and the jack-plug connections dodgy.

Now, this is the point where things get contentious amongst gear-heads; the Booster could be termed a vintage pedal, and though not strictly a collectible (or even all that desirable or valuable), swapping out components just isn't the done thing. Working or not, this clone might be worth something to someone, so it didn't feel right to be messing with it.

While the owner didn't care so much about that side of it, I pointed out some potential problems with what he intended to do with it. He'd been doing some internet research and like many guitarists, had been swayed by the fact that many of his heroes had used a similar device in their recording and stage setups.

He wanted to add this Tone Booster to his existing pedal-board effects chain and have it powered by the board's 'daisy-chained' 9V power supply.

I informed him that while this could likely be achieved, it would mean overcoming considerable electronic hurdles, and the benefits of doing that were probably not as desirable as he might think.

For a start, this effect was either on or off, and turning it off would kill the signal from that point onwards. Modern effects use a bypass system, where stomping on a heavy-duty DPDT (or 3PDT) switch adds or removes the effect from the signal loop; this box only had a small, case-mounted on/off switch, unsuitable for switching with one's foot anyway.

Plus, adding a bypass system would completely ruin the original aesthetic of the Booster.

Then there was another more complex issue; this device uses a germanium PNP transistor; therefore, the circuit could be termed 'positive ground', with the battery positive terminal connected to the case.

Running it from a negative-ground power supply wasn't going to be simple, especially if it is connected to his other pedals, as the input and output would essentially be shorted to ground.

Again, while this could be overcome, it would completely change the Booster's original look.

Over the years, I'd met several constructors and heard of many others who had successfully modified vintage pedals, or made their own versions.

So my advice to the customer was to leave the original as-is and create a whole new pedal using a more modern case, negative-earth supply and a bypass system but using period components and circuitry. The idea was to try to achieve the same overall sound.

He went away and thought about it and came back with the mandate to go ahead, although he had some reservations about being able to get the same sound as the original Booster.

Designing a new old pedal

I reverse-engineered the circuit and found it was a clone of the much-coveted Dallas Rangemaster, a widely-copied 60s-era Tone Booster supposedly bearing mythical powers.

Just what made it so great is up for debate, as it is generally accepted that every Rangemaster gave a slightly different sound due to the 'use-whatever-is-in-the-parts-bin' approach to manufacture and the relatively wide component tolerances of the era.

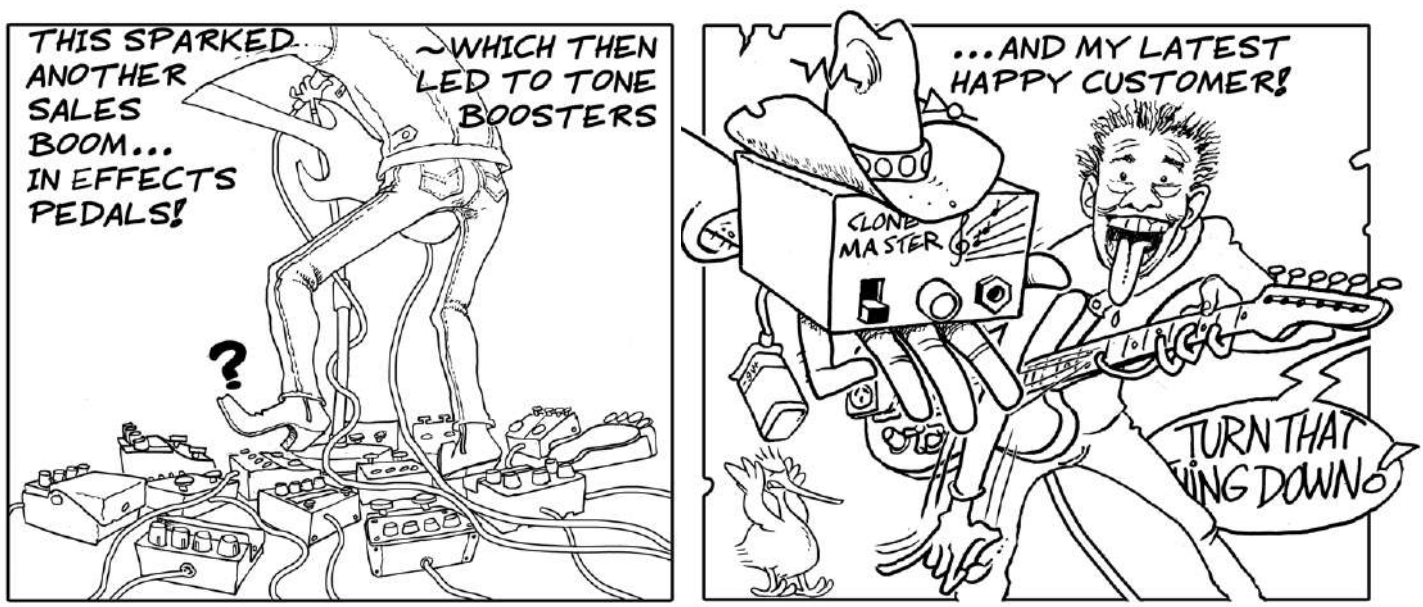
What is known is that almost all the great guitar players over the years have either used one at some point in their careers, or raved at length about it in magazines and videos.

As most of the industry tech guys I knew who'd done this kind of work have long-since settled down into middle-aged obscurity, I hit the web and was gratified to discover that there is a thriving sub-culture dedicated to the Rangemaster, and they'd already done all the research and development into modernising the pedal.

As there was no point re-inventing the wheel, I cherry-picked what I wanted and drew up a circuit incorporating all the various mods required for modern stage use, whilst retaining as much of the original circuitry as possible.

Nutting out the design

That meant sticking with a germanium PNP transistor and using vintage carbon-composition resistors


THIS SPARKED ANOTHER SALES BOOM... IN EFFECTS PEDALS!
~WHICH THEN LED TO TONE BOOSTERS
?
...AND MY LATEST HAPPY CUSTOMER!
CLONE MASTER
TURN THAT THING DOWN

and polyester or film capacitors. This posed no problems for me, because I have drawers packed with NOS (New Old Stock) components collected over the last 40 years, many of which are from dad's collection and date back to the 60s.

I have many AC and OC-series transistors that will do the job, along with hundreds of various values of old capacitors, resistors and potentiometers.

All I needed from my stash was one PNP transistor, four capacitors, one pot and two resistors for the basic booster circuit. I also decided to add three different-value, switchable input caps to offer a wider range of tone choices, since modern pickups are typically hotter and sound different from those from the olden days.

I also added input pull-down and output resistors, which are not necessary when the Booster is used as a stand-alone effect but are preferred when used in conjunction with other pedals, to match impedances and minimise switching noise.

Another modification I made is to use a trimmer pot instead of one of the originally fixed bias resistors, to help with fine-tuning the transistor operating point and hopefully enable us to dial in the perfect tone.

I also decided to use a transistor socket, so I could experiment with other transistors to get different sounds. I also included a foot-operated total bypass switching system, which completely removes the booster circuit from the signal loop, without affecting anything else.

By today's standards, this is a flawed circuit, with non-optimal input and output impedances and noisy, 'old-tech' components, all expected to interface with modern, high-gain electronics. Regardless, many guitarists will put up with noisy pedals (or use gates or other methods of minimising noise) to get a better overall tone, so this isn't a show-stopper.

A different power supply arrangement

Nonetheless, I still had to modify the original circuit slightly to use a negative ground, so we can plug in other pedals and use the customer's existing power supply. This modification should not affect the tone.

Initially, I thought I would simply be able to switch the existing ground and signal points at the jack sockets while keeping the rest of the circuit above ground. But this turns out not to be a good idea as it can cause circuit instability and add more noise.

The solution was to use a power-converter board to manipulate the voltage polarity instead; this ensures the circuit functions as originally intended, while still making the Booster compatible with the modern power supply and other pedals in the signal chain.

In case the customer wanted to use the pedal as a stand-alone effect, or off-grid, I added the ability to run it off its own 9V battery.

I utilised the power socket's second set of contacts to take the battery out of circuit when external power is plugged in. I also used a stereo jack socket for the signal input, so power is switched on when the mono input jack is plugged in; this is standard with newer pedals.

I chose a solid, cast-aluminium enclosure for the case as this will stand up well to the 'rock-and-roll' life of a floor-mounted effects pedal. It also supplies a stable platform for stomping on the heavy-duty bypass switch. These cases are now inexpensive and widely available from many vendors.

Putting it all together

Construction was very straightforward; much of the hard work is drilling the case for the various components. It is certainly far simpler to build than the DAB+ Radio I've just assembled (**siliconchip.com.au/Series/330**). That project is a real test for constructors!

Setup is also easy, with nothing much to do. To start off, I plugged a recommended OC44 transistor into the socket. I then hooked up a power supply, my guitar and a 15W valve amplifier, so I could tweak the bias voltage by adjusting the bias trimmer to get the most pleasing sound.

The Booster certainly makes a big difference; through it, my Telecaster sounds bright and punchy. The Booster at full volume drives my 12AX7 preamp into a very pleasant crunch. Switching the input capacitor selector to other values made quite a tonal difference, but I think this will vary widely depending on what guitar is used.

Regardless, the customer was delighted when he heard me playing through his new pedal, and later called to tell me it sounded fantastic, if a little noisy, through his setup. But that's all part of the vintage charm. Job done!

Weston voltmeter repair

D. V., of Burpengary, Qld, got a very unusual request lately. He was asked to repair a Weston voltmeter.

Haven't heard of Weston? I can't blame you. The Weston Electrical Instrument Company existed from 1888 to 1954. They were one of the early electrical pioneers and this is the great-great-grandfather of the multimeter which we all use today. This is what happened next...

Being an old and long retired electrician, the request to repair the Weston voltmeter aroused my interest. I was keen to see how it was made and whether I could get it working. So I duly agreed and waited for the instrument to show up at my door.

It arrived carefully packed in an aluminium carry case. Inside was a neat, polished timber box, possibly American redwood, measuring 200 x 180 x 100mm deep – or should that be 8 x 7 x 4 inches?

The label inside the lid described it as a "WESTON Standard Portable Alternating and Direct Current Voltmeter, No: 123" with an accuracy of 1/5 of 1%! The date it was tested in the Weston Laboratory was August 20th, 1891. The label states (paraphrased):

"This instrument indicates Legal Volts. It has been standardized for use in a HORIZONTAL position, and to obtain the most accurate results, should be used in that position. It is absolutely permanent, and if properly used, its indications may be relied upon to within 1/5 of 1%.

Resistance of 60 volt coil at 70°F: 1107.72 Legal ohms

Resistance of 120 volt coil at 70°F: 2224.11 Legal ohms

Standardized at Weston Laboratory, Newark N. J., U.S.A.

Date: August 20th, 1891 By Wallace Hill, Certified: Edward Weston

Do not handle this instrument roughly. Rough usage is liable to injure the jewelled bearings, or pivots, and thus cause friction and diminish the sensibility of the instrument.

Avoid wiping the glass cover just before making a reading. Neglect of this rule frequently causes great discrepancies in the readings of electrical measuring instruments, owing to the

WESTON STANDARD PORTABLE
and Direct Current Voltmeter No. 123
Do not handle the instrument roughly; rough usage of it is liable to injure the jeweled bearings or pivots, and thus cause friction and diminish the sensibility of the instrument.
Avoid wiping the glass cover just before making a reading. Neglect of this rule frequently causes great discrepancies in the readings of electrical measuring instruments, owing to the fact that the rubbed parts become electrified and the moving parts are electrified by induction, and are therefore subjected to forces other than those they are intended to measure.
Carefully read the instructions for use accompanying the instrument before attempting to use it.
WESTON'S
DIRECT READING
VOLT-METER.
No 123
PATENTED.

The Weston Voltmeter dated at 1891, with a view of its internals directly below. The paper sleeve remarks that the glass cover should not be wiped before testing as the rubbed parts become electrified.

fact that the rubbed parts become electrified and the moving parts are electrified by induction, and are therefore subjected to forces other than those they are intended to measure.

Carefully read the instructions for use accompanying the instrument before attempting to use it."

Well, the instructions had disappeared long ago as the instrument was acquired somewhere in the 1940s. Nobody knew where it had spent the previous 50 years of its life.

The meter movement sits behind a thick glass panel, held in place with a single screw. I thought it would be a moving iron meter as the scale is cramped at the beginning.

But removing the works revealed a rather large moving coil assembly with two wound field coils. There is a timber bobbin with silk-covered resistance wire wound on it, to provide for the two voltage ranges, 120V and 60V.

Mounted on the glass panel is a small multi-position rotary switch with small wire resistors between the contacts. The scale is marked 60° to 105°, no doubt in Fahrenheit! The switch was very stiff with age and a few of the resistors and switch contacts measured open-circuit.

A mercury thermometer is mounted under the glass, with its bulb curved around so that it is close to the field coils. You set the knob to match the temperature on the thermometer to compensate for the change in the resistance of the coils as they warm up.

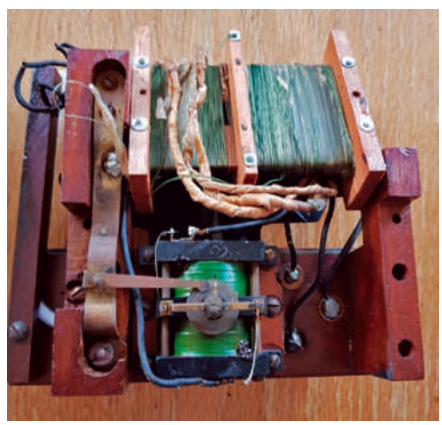
The moving coil is wound in a ring with the jewelled pivots glued on. There is no metal former as in a modern moving coil instrument, so there is no damping of the meter movement. The stator coils are wound on Bakelite formers. The moving coil pivots are mounted between the two coils with the hairsprings which carry the current to the coil.

Also, it has a disc brake. Because the meter has no damping, a change in reading will cause the pointer to swing like a pendulum. By easing the pressure on the Operate button a little, a small brake pad touches the disc and steadies the pointer. Press the button right in and the pointer will settle at the correct reading within 1/5 of 1%, apparently!

The original wiring was rubber insulated, and after 127 years it had crumbled away, so I replaced it with plastic-insulated wire.

I checked the meter accuracy against a Fluke 87 multimeter as my calibrator couldn't provide the required current. It takes 50mA for full-scale deflection! Initial testing showed an error of about 2% on the 60V range and about 4% error on the 120V range. This was better than I expected for such an old instrument.

I decided to shunt the bobbin resistors with wire-wound resistors to improve the accuracy a little. These could be hidden, tucked away inside the instrument. The accuracy was then



about 2%, which was deemed good enough for a museum piece.

How did Mr Weston achieve the stated accuracy of 1/5 of 1%? Probably by setting everything up in ideal conditions in his laboratory. The meter would have had only the curved lines on the dial. A precise voltage would have been applied and a small mark put on the scale. This would have been repeated over and over until all the major marks were made.

Then a very talented and neat artist would mark up all the necessary calibration points. So the accuracy would be within 0.2% of his instruments, at least initially. How long it remained that accurate, it's hard to say.

Having gotten it working satisfactorily, I popped it back into the carry case and sent it back to the museum, where it will no doubt fit in nicely.

Car start-stop battery bodge

A. K., of Armidale, NSW had to use some lateral thinking to overcome a design flaw in his car. You have to wonder why the engineers who designed it didn't think of this in the first place...

I purchased a new SUV five years ago. While gazing into the engine compartment, I noticed that it had a big 12V battery – much larger than I was expecting it to be. I was to find out why that was the case shortly.

This car has a feature called the idle stop-start system (ISSS), where the motor shuts down if the brake pedal is held down for more than a few seconds. It starts up automatically as soon as you take your foot off the brake again. This is starting to become more common, and some people hate it. But it does explain why the vehicle needs such a large battery – to allow for the frequent cranking that results.

The ISSS feature is designed to save petrol and reduce car emissions in cities. It's OK in a city when you're frequently stopping at traffic lights but in a small town with lots of roundabouts, it can be a problem!

Three years after I purchased the car, the ISSS fault lamp started blinking. I was told by the service department that this indicated when the battery was down to 75% of its full charge. They told me to make sure the battery electrolyte was topped up and take it for a long drive, or use a mains charger and that would fix it.

And it did, for nine months, then the lamp started flashing again. This time, the service department gave the battery a thorough test, which it passed with flying colours. However, within six months, the flashing was back to stay. The service department's answer was for me to buy another battery!

But the batteries had lasted much longer than five years on my four previous cars, so I took exception to this.

I have worked extensively with 12V lead-acid batteries used for emergency power over my 40-year career as a broadcast technician.

I always refilled them with distilled water, using a hydrometer to check the cells and I do the same with my car batteries. The car doesn't crank long before it starts and it starts every time. I never saw a battery voltage below 12.3V. So it should still be in good condition.

I started wondering why I was having this problem and decided that the ISSS system must be especially hard on the battery or especially fussy about its condition.

Perhaps the battery's impedance had increased as it aged and that was causing the problem. So I needed a way to reduce the battery's impedance to a more normal level.

Then I remembered my old mentor technician (boss) soldering a 1000µF capacitor across a 9V radio battery, extending its life by quite a bit. Perhaps a capacitor across my car battery would do the same. But it would need to be much bigger than 1000µF!

Back in the 90s, one Farad capacitors were all the rage for use with car sub-woofer amplifiers. I dropped into the local car hifi shop and luckily picked up an old one off the shelf for a good price, as new 1F capacitors are $150-200.

I attached the capacitor to the car battery holder as close as possible and wired it in parallel, keeping the leads short. I was disheartened that after starting the car, the ISSS lamp was still flashing. But the next day, the ISSS lamp didn't flash and for the past six months, the flashing has not returned. I consider that a success!

I have more recently become aware that some car manufacturers (mine in particular) manipulate the battery charging voltage. I checked my battery voltage with the engine running and got a reading of just 12.55V. I was expecting at least 13V, so what is going on?

Then I remembered a letter in Mailbag (Silicon Chip; September 2018), where a car owner found his car would only properly charge the battery when the lights were on.

I then turned on the headlights to main beam and lo and behold, the battery charge voltage went up to 13.8V. Even switching on the parking lights did the trick.

Perhaps this was the other reason my car battery was not aging well. I don't drive much at night and with the lights off, perhaps it was never being fully charged.

I suggest readers who own newer vehicles may want to monitor their battery charging voltage, to make sure it is getting charged adequately from time to time.

Fisher & Paykel fridge repair

D. M., of Toorak, Vic made a simple repair which saved his friend hundreds of dollars and no doubt, lots of frustration. He's very annoyed at the situation, and we can't blame him…

I have a friend with a Fisher and Paykel "French door" fridge. It was giving an F20 error code. A Google search explains this is due to a broken wire that goes from a door to the body of the fridge. The wire is evidently for a heating element.

The wires are located under the upper-left hinge cover which snaps off. She had previously had this problem repaired several times by a technician sent by F&P, and she paid $400 each time. She wanted me to look at the fridge and see if I could stop it from failing repeatedly.

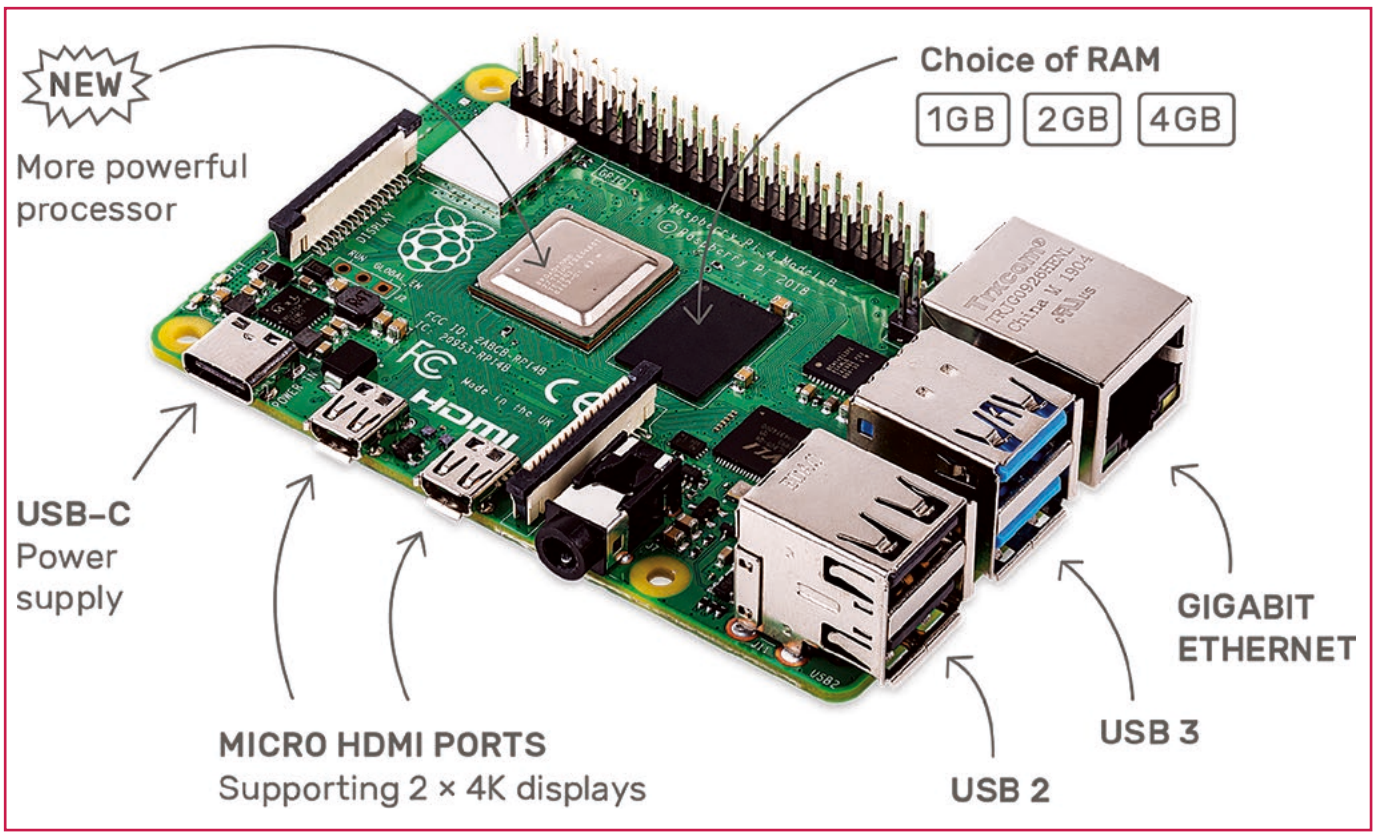
It only took me a few minutes to get to the wires in question, and they appeared to be ordinary wires, not a type specially designed to be fatigue resistant, as you would expect in a situation where they can be repeatedly bent and unbent dozens of times per day.

Multiple breaks in these wires had been repaired with wire joiners. I removed all evidence of the previous repairs and soldered new high-quality wires of similar thickness in their place. I think my repair will last a long time.

It took me about thirty minutes in total, and I think it is outrageous that she paid $400 on multiple occasions to the same person for essentially the same repair. Especially since the fault appears to be due to a design flaw, ie, using an inappropriate type of wire for this application. SC

The new Raspberry Pi 4B

The Raspberry Pi 3B+ was introduced only about one year ago. The Raspberry Pi foundation has clearly been busy in the meantime as they have just announced the release of the Raspberry Pi Model 4B. It's more than just another upgrade . . . with several delicious new features (as you can see below), it's a whole new pie!



The Raspberry Pi series of single-board computers (SBCs) has proven immensely popular, with around 20 million sold since the launch of the first model, around seven years ago.

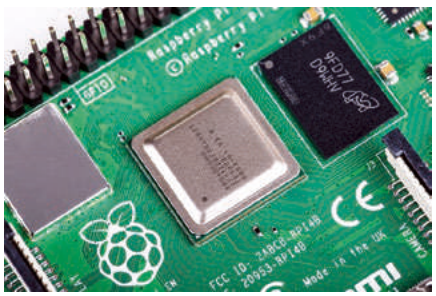
We reviewed the most recent model, the 3B+, in our July 2018 issue (siliconchip.com.au/Article/11141).

The Pi 4B is similar in many ways to the 3B+, but it is somewhat more powerful.

What's in the Pi?

The Raspberry Pi Foundation is touting the Pi 4B as "your new desktop computer".

We've tried using some of the older variants as a desktop computer, and while they are usable under light load, they struggle with, for example, large numbers of browser tabs.



But the Pi is very powerful compared to most embedded controllers, so in a sense, it bridges the gap between the microcontroller and desktop worlds.

The Pi 4B now has options for 1GB, 2GB or 4GB of RAM, which is a considerable step up from the maximum of 1GB in the older version (it wasn't that long ago that PCs struggled to address 4GB!).

The RAM is also more than double the speed now. That alone will make a massive difference in performance, especially for desktop applications.

The main SoC (System on a Chip) processor is now an ARM Cortex A72 made with a 28nm process, compared to the 40nm process used for the Cortex A53 in the 3B+.

The A53 was a "high-efficiency core" while the A72 is a "high-performance" core.

That means it has more cache memory, supports out-of-order execution and has a 15-stage pipeline, compared to the 8-stage pipeline of the A53.

The A72 also has a more advanced branch predictor and runs slightly faster, at 1.5GHz rather than 1.4GHz.

All these changes mean that you can expect code to run about 60% faster on the Pi 4B than it did on the Pi 3B+.

Raspberry Pi 4 specs

SoC: Broadcom BCM2711B0 quad-core A72 (ARMv8-A) 64-bit @ 1.5GHz

GPU: Broadcom VideoCore VI

Networking: 2.4GHz and 5GHz 802.11b/g/n/ac wireless LAN

RAM: 1GB, 2GB, or 4GB LPDDR4 SDRAM

Bluetooth: Bluetooth 5.0, Bluetooth Low Energy (BLE)

GPIO: 40-pin GPIO header, populated

Storage: microSD

Ports: 2 × micro-HDMI 2.0, 3.5mm analog audio/video jack, 2 × USB 2.0, 2 × USB 3.0, Gigabit Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)

Dimensions: 88mm × 58mm × 19.5mm, 46g

Communication upgrades

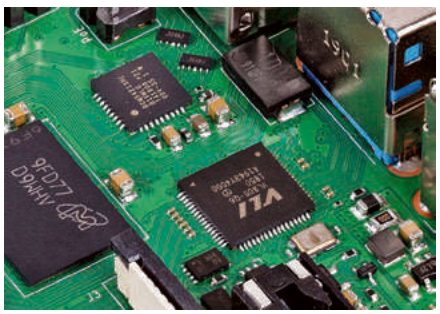
The Gigabit Ethernet port is now usable at true Gigabit speeds, as it no longer communicates with the CPU over USB, and two of the externally accessible USB ports are now USB3 types.

Dual micro-HDMI sockets replace the single full-size HDMI socket found on the older models. For those folks who like a dual monitor setup, this suddenly got a lot easier with a Raspberry Pi.

All these features will certainly make the new Pi 4B more usable as a desktop computer.

There are a few other minor changes. It's powered via a USB-C connector, and the micro-HDMI sockets mean a different cable or adapter is needed.

These changes, and the rearrangement of the Ethernet and USB ports, mean that existing cases will not fit the new model.

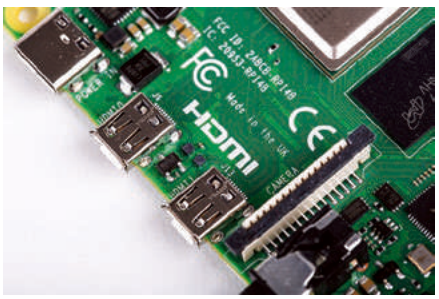


There are also some changes to the way the Pi boots; there is now a boot EEPROM on the board itself which replaces the bootcode.bin file previously stored on the SD card.

Support for PXE (network) and USB booting should be available with a future firmware upgrade.

The Raspbian operating system has also stepped up, with the most recent version (June 2019) changing to Debian's "Buster" release.

We expect that you will need this new version of Raspbian to operate the new version of the Pi.



Conclusion

It appears that the Pi 4B now has the necessary grunt to truly become a desktop computer and we expect it will be quite popular as new users become more willing to try it out.

It's also likely to be hard to beat in performance/price ratio as an embedded controller.

As we are writing this article, only the 1GB variant appears to be in stock (at Core Electronics), although we expect demand to be high.

All three models should be available in quantity around the end of September, but you can place a pre-order now (and we recommend that you do so, as they may sell out fast!).

The Pi 4B starts at around $56 (not including a power supply, SD card or cables); the 2GB model $72 and the 4GB model $88 (all prices including GST).

See the following websites for more details:

- www.raspberrypi.org/products/raspberry-pi-4-model-b/
- https://au.element14.com/buy-raspberry-pi
- https://core-electronics.com.au/raspberry-pi/boards.html

SC

DRIVING AT NIGHT? LOSING NIGHT VISION DUE TO THE BRIGHT LIGHTS *INSIDE* YOUR VEHICLE?

YOU NEED THIS

Radio Head Unit Dimmer Adaptor and Voltage Interceptor

by John Clarke

Very few aftermarket car radio 'head units' offer a dimming function, which makes driving in the country at night downright hazardous. This simple device fixes that, adjusting the display and backlighting brightness as you dim your instrument lights, giving you back your night vision and letting you see properly! It can also be used as a basic Voltage Interceptor for various automotive sensors.

When driving at night, especially outside of towns and cities where there are no street lights, your eyes need to adapt to the dark.

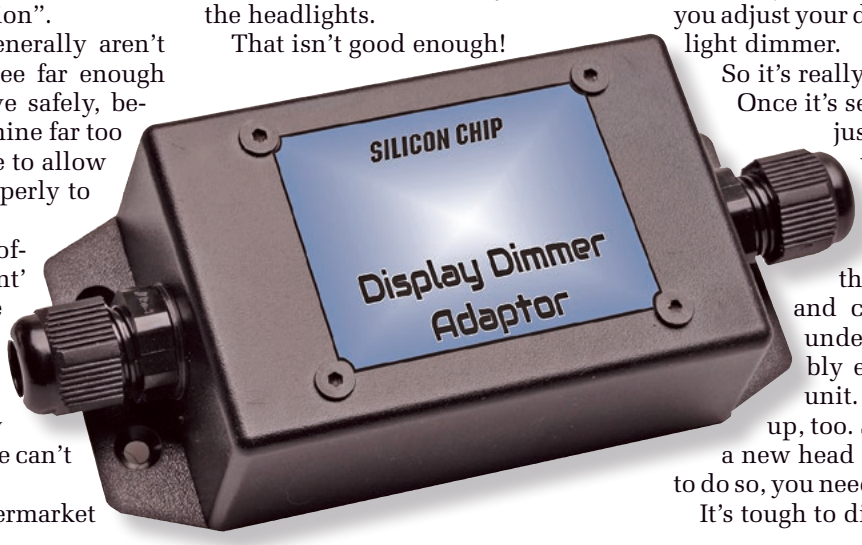
It's called "night vision".

Bright headlights generally aren't sufficient for you to see far enough down the road to drive safely, because many vehicles shine far too much light at your face to allow your eyes to adapt properly to the dark.

One especially bad offender is 'infotainment' screens; while these generally dim automatically at night (ie, when your headlights are on), they're usually still far too bright. Some can't be turned off at all.

And if you fit an aftermarket 'head unit' to your car, to add new features like Bluetooth or MP3 playback (or just to enhance the sound quality), you will usually find that the display doesn't dim at all when you turn on the headlights.

That isn't good enough!



This device was designed specifically to solve that problem. Not only does it allow you to dim the display of a typical head unit automatically, but it will adjust the display brightness as you adjust your dashboard instrument light dimmer.

So it's really convenient.

Once it's set up, you simply adjust your dash lights to the desired brightness, and the radio will follow suit.

It's a small unit that draws little power and can be hidden away under the dash or possibly even inside the head unit. It's quite easy to set up, too. So if you've installed a new head unit, or are planning to do so, you need to build this device.

It's tough to dim the head unit dis-

play without it, since most aftermarket radios don't have any wires to control the display brightness.

So to be able to dim the display, you will need to open it up and find the display backlighting supply source. This is then intercepted and adjusted by our Dimmer Adaptor. In most cases, this is not hard to do for anyone with a little electronics knowledge; we'll explain how to do this later on.

Why we had to design this device

Part of the reason you need this Dimmer Adaptor is that typically, the switch lighting and alphanumeric display in the head unit are backlit by LEDs, whereas the instrument backlighting in most vehicles more than a few years old uses incandescent lamps.

The dimming voltages required are quite different between LEDs and incandescent lamps.

For example, the head unit may use two white or blue LEDs connected in series to illuminate the buttons, and these will likely be driven from a regulated supply of about 8-9V via a current-limiting resistor. So 8-9V would give full brightness while around 6V would cause them to barely light up at all.

Compare that to 12V incandescent lamps, that still give some light down to below 1V. Additionally, incandescent lamps have a brightness that is very non-linear with supply voltage.

Even if your vehicle has backlit instrument lamps that use LEDs, their operating voltage range will not necessarily be suitable for head unit display dimming.

Our Dimmer Adaptor works in either situation.

One final aspect to note is that the dimming control voltage for instrument lamps drops to 0V when the parking lights and headlights are off. However, the radio head unit should have its backlighting at maximum brightness during the day.

This requirement is also catered for by our Dimmer Adaptor.

That's because its output voltage can be set to a particular value corresponding to various instrument dimming voltages in up to 16 steps.

When the input voltage is between two of the programmed values, the output voltage is linearly interpolated so there is not a sudden change as the instrument light brightness is adjusted.

Figs.1(a) & (b) show two examples of how the Dimmer Adaptor can be configured to operate.

In Fig.1(a), the unit is programmed to deliver 8V at the output when its input is 0V, then reduce its output to 6V as the input voltage increases to 1.6V, then the output rises again, finally reaching 8V when the input is at 12V.

This has the effect of giving maximum display brightness (8V for two white/blue LEDs in series) when either the headlights are off, or the instrument lights are at the maximum brightness setting.

As the instrument lights are dimmed, the LED drive voltage smoothly drops towards 6V, which would give minimal display backlighting on the head unit.

Fig.1(b) demonstrates how the linear interpolation works. Here, five different points have been programmed in. The black lines show what the result would be without interpolation, and

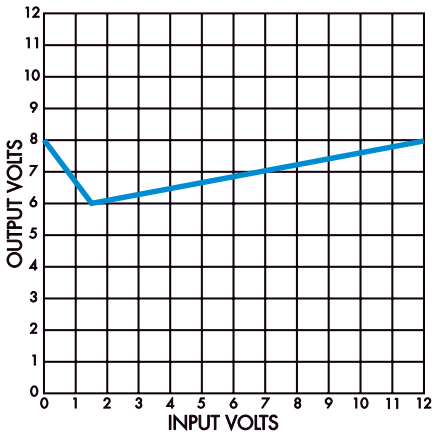


Fig.1(a): the unit's output voltage varies smoothly as the input voltage varies. This example suits a typical head unit with LED backlighting. As the input voltage ranges from 12V down to 1.6V, the LED drive voltage drops from 8V to 6V. With the instrument lights off, the backlight goes to full brightness.

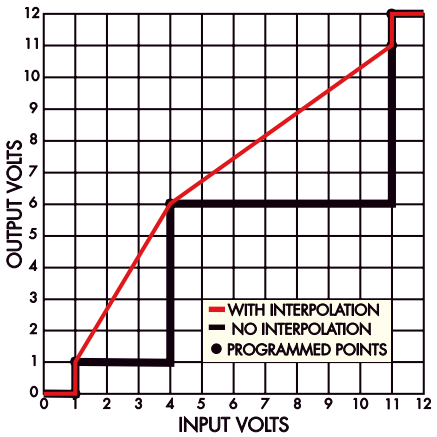
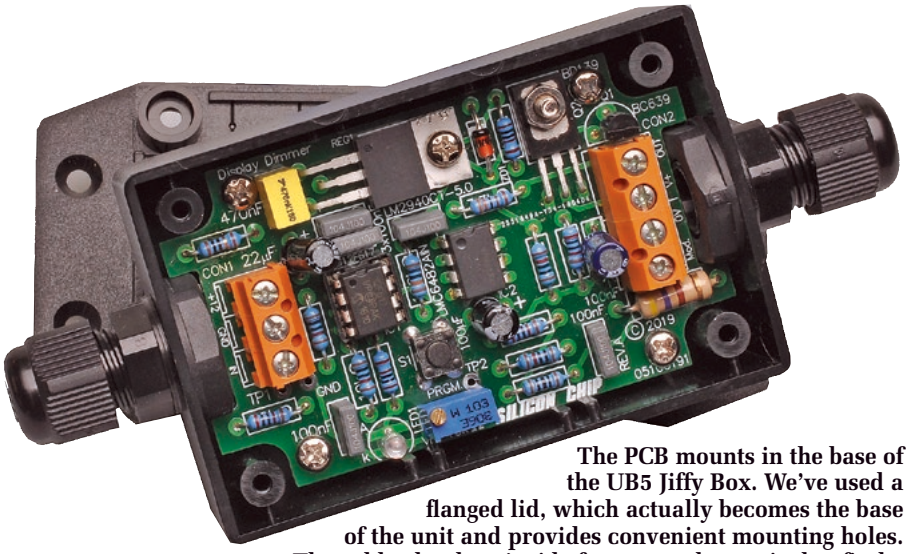


Fig.1(b): a more complicated example, with five voltages defined. Without interpolation (black lines), the output voltage would jump to the next set point as soon as the input voltage reached the defined threshold. The interpolated output (red) provides a linear variation between the set points instead.

Features

- Compact unit
- Suitable for use with voltage or PWM based instrument dimming
- Maps output voltage against input voltage
- Easy setup of the adaptor
- Voltage follower or PWM output with 500mA current rating
- Voltage modifier output (low current signal)
- 16 programmable input voltage steps available
- Interpolation for output between each input voltage step
- Adjustable output change rate and smoothing



The PCB mounts in the base of the UB5 Jiffy Box. We've used a flanged lid, which actually becomes the base of the unit and provides convenient mounting holes. The cable gland nut's side faces must be vertical to fit the PCB cutouts.

the red line shows the result with interpolation.

You can see that it's much smoother.

Using more points would help to give a good brightness correspondence between incandescent and LED lamps.

Circuit description

The circuit of the Dimmer Adaptor is shown in Fig.2. It is based around microcontroller IC1, a PIC12F617-I/P.

The vehicle's 0-15V instrument light dimming voltage is applied to CON1. This is reduced to a 0-5V signal by the 20kΩ/10kΩ resistive divider and filtered by the 100nF capacitor, then applied to pin 3 of IC1.

This pin is its AN3 analog input and converts the 0-5V at that pin into a digital value of 0-1023 using its internal analog-to-digital converter (ADC).

This is then used to control the duty cycle of the 7.8kHz pulse width modulated (PWM) waveform at its pin 5 output.

The PWM signal is smoothed using an RC low-pass filter comprising a 100kΩ resistor and 100nF capacitor. This gives a voltage which is proportional to the PWM duty cycle, at pins 2 & 5 of dual CMOS op amp IC2.

Half of this op amp, IC2b, buffers and amplifies the filtered PWM voltage. It has a gain of three, set by the ratio of the 20kΩ and 10kΩ feedback resistors, giving it a 0-15V output range, assuming that the supply voltage is high enough (otherwise, the upper limit is set by the supply voltage). The 100nF capacitor across its feedback resistor limits its output voltage slew rate to provide further filtering.

The 0-15V signal from this op amp is fed to the "MOD OUT" terminal of CON2 via a 100Ω resistor, which isolates the op amp output from any external capacitance and also provides some protection in case of a short circuit or if a voltage is accidentally fed back via this pin.

As mentioned earlier, the smoothed PWM signal is also fed to pin 2 of IC2a, which is the inverting input of the other half of the dual op amp.

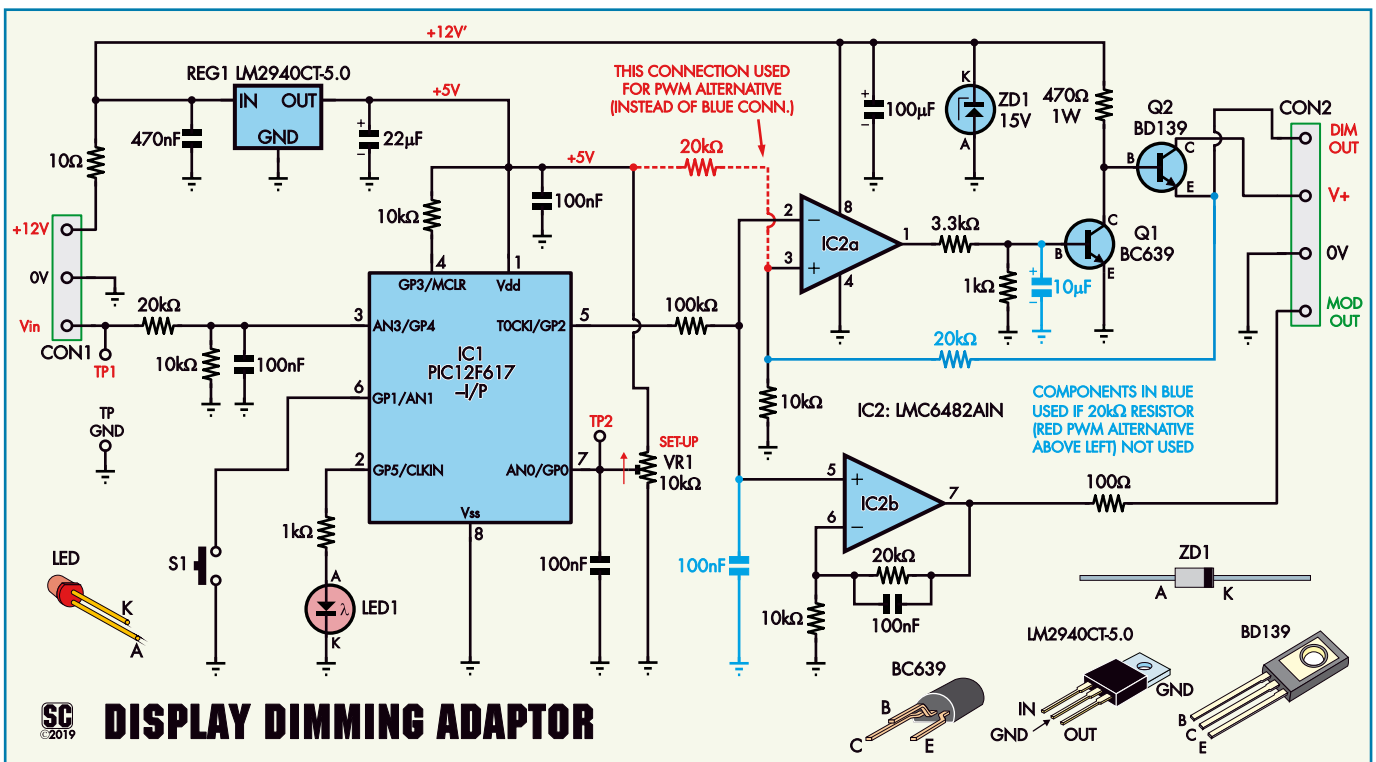


Fig.2: the Dimmer Adaptor circuit is based around microcontroller IC1, dual op amp IC2 and transistors Q1 & Q2. IC1 monitors the drive voltage to the instrument lights at its AN3 analog input (pin 3) and produces a PWM waveform at its output (pin 5). This is smoothed to give a varying DC voltage, and op amp IC1a drives transistors Q1 and Q2 to varying the head unit backlight drive voltage at DIM OUT.

This op amp drives the base of NPN transistor Q1 via a 3.3kΩ/1kΩ voltage divider, with a 10µF capacitor helping to filter out any remnants of the PWM waveform.

Since Q1 is configured as a common emitter amplifier, it has the effect of inverting the signal from IC2a, ie, if the voltage at the output of IC2a rises, Q1 conducts more current and so its collector voltage drops. Similarly, if the output voltage of IC2a falls, Q1 conducts less current and its collector voltage increases, pulled up towards the 12-15V supply voltage by the 470Ω resistor.

This inverted voltage at the collector of Q1 is then buffered by emitter-follower Q2, with the resulting voltage fed to the "DIM OUT" terminal of CON2. The voltage at this point is also fed back to input pin 3 of IC2a, the non-inverting input, via another 20kΩ/10kΩ divider, to translate the 0-15V at the output back to 0-5V at this pin.

The reason for this seemingly odd configuration is to control the current to the radio's LED display, and therefore its brightness.

The V+ terminal is connected to the supply voltage for this LED display, but the track feeding that voltage to it is cut and connected to the "DIM OUT" terminal instead. So how much current is conducted by Q2 determines the display brightness.

The feedback goes to the non-inverting input of IC2a, and the control signal to the inverting input, simply because its output voltage is inverted by Q1.

By swapping around the inputs, we 're-invert' the way it operates, therefore giving it negative feedback so that its output will stabilise at the desired voltage, as determined by the filtered PWM signal.

The 10µF capacitor at Q1's base not only filters this signal further but also provides loop compensation, slowing down its response rate and thus preventing high-frequency oscillation due to the extra loop phase shift introduced by the two added transistors.

Alternative PWM drive arrangement

As we shall explain later, linear control of the head unit backlighting may not provide equal dimming between the LED display and switch backlighting. This can be solved by getting rid of this linear control and instead, switching the lights on and off rapidly, varying the duty cycle to control the brightness – ie, direct PWM control.

This can easily be achieved by a few simple changes to the circuit. The feedback resistor from DIM OUT to pin 3 of IC2a is eliminated, and instead, it connects pin 3 to the +5V rail, as shown in Fig.2.

Pin 3 of IC2a then has a constant voltage applied of around 1.66V (5V ÷ 3). The 100nF capacitor that filters the voltage at pin 2 of IC2a and the 10µF compensation capacitor at the base of Q1 are also removed.

IC2a then acts as a comparator, and its output will go high when its pin 2 voltage is below 1.66V and low when it is above 1.66V. When its output is high, Q1 switches on and pulls Q2's base down, switching it off. And when its output is low, Q2's based is pull up by the 470Ω resistor, switching it on.

As a result, backlight current can flow whenever the pin 2 voltage is above 1.66V.

Power supply

The circuit is powered from the vehicle's 12V ignition switched supply, which is wired to CON1. Power flows from there to the input of automotive 5V regulator REG1 via a 10Ω resistor.

The resistor and 470nF decoupling capacitor filter out any voltage transients, reducing their amplitude

Parts list – Head Unit Dimmer Adaptor

1 double-sided PCB coded 05107191, 77 x 47mm
1 UB5 Jiffy box (optionally with flanged lid)
[Jaycar HB6016, Altronics HF0205]
1 3-way PCB-mount screw terminal, 5.08mm spacing (CON1)
2 2-way PCB-mount screw terminals, 5.08mm spacing (CON2)
1 8-pin DIL IC socket
1 SPST tactile momentary pushbutton switch (S1) [Altronics S1120, Jaycar SP0600]
9 M3 x 6mm panhead machine screws (for Q1 and PCB mounting)
1 M3 x 10mm panhead machine screw (for Q2)
2 M3 hex nuts
4 12mm long M3 tapped spacers
2 IP65 cable glands to suit 3-6.5mm diameter cable
Automotive wire, solder, connectors, self-tapping screws etc

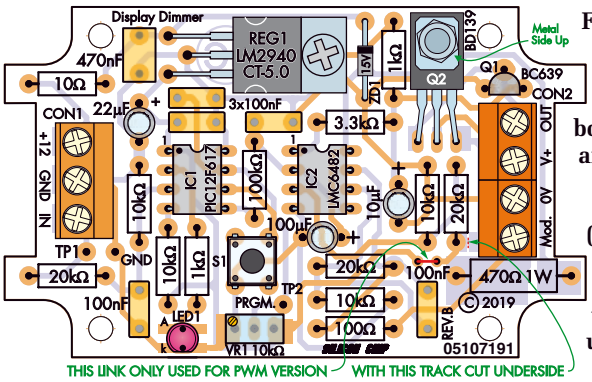
Semiconductors
1 PIC12F617-I/P microcontroller programmed with 0510619A.HEX (IC1)
1 LMC6482AIN dual CMOS op amp (IC2) [Jaycar ZL3482]
1 LM2940CT-5.0 automotive 5V regulator (REG1)
1 BC639 500mA NPN transistor (Q1)
1 BD139 1.5A NPN transistor (Q2)
1 3mm high brightness red LED (LED1)
1 15V 1W zener diode (ZD1) [eg, 1N4744]

Capacitors
1 100µF 16V PC electrolytic
1 22µF 16V PC electrolytic
1 10µF 16V PC electrolytic
1 470nF 63V MKT polyester
5 100nF 63V MKT polyester

Resistors *(all 0.25W, 1% metal film unless otherwise stated)*

	4 band code		*5 band code*
1 100kΩ	*brown black yellow brown*	*or*	*brown black black orange brown*
3 20kΩ	*red black orange brown*	*or*	*red black black red brown*
4 10kΩ	*brown black orange brown*	*or*	*brown black black red brown*
1 3.3kΩ	*orange orange red brown*	*or*	*orange orange black brown brown*
2 1kΩ	*brown black red brown*	*or*	*brown black black brown brown*
1 470Ω 1W, 5%	*yellow violet brown gold*	*or*	*yellow violet black black gold*
1 100Ω	*brown black brown brown*	*or*	*brown black black black brown*
1 10Ω	*brown black black brown*	*or*	*brown black black gold brown*

1 10kΩ multi-turn top adjust trim pot (VR1) [Bourns 3296W or similar]



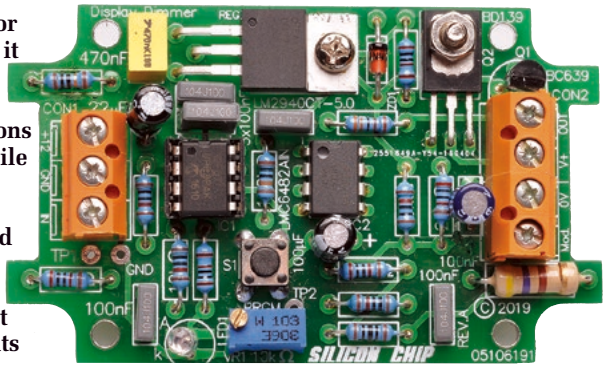


Fig.3: the Dimmer Adaptor PCB is quite compact so it can fit inside the head unit, or a UB5 Jiffy box. The vehicle connections are on the left (CON1) while the head unit wires are connected on the right (CON2). Trimpot VR1 and tactile switch S1 are used to configure the unit. Once it has been set up, no further adjustments need to be made.

significantly by the time they reach REG1's input.

This LM2940CT-5.0 regulator is not damaged with a reversed supply connection or transient input voltage up to 55V for less than 1ms. Its output is stabilised by a 22µF filter capacitor. The resulting 5V supply powers microcontroller IC1.

Dual op amp IC2 is powered from the nominally 12V supply via the same 10Ω resistor, but there is also a 15V zener diode (ZD1) across the supply, to protect the op amp from transient voltage spikes.

This supply is also smoothed by a 100µF capacitor.

Additional components

Trimpot VR1 and pushbutton switch S1 are used to set the unit up. VR1 is connected across the 5V supply with its wiper going to pin 7, the AN0 analog input. IC1's internal ADC can sense the voltage at this pin and thus sense the trimpot's rotation.

Test point TP2 is used to measure the voltage at pin 7 during the setup procedure, described below.

VR1 is also used to set the unit's response time once it has been set up, which will be explained in more detail later.

S1 is connected between digital input GP1 (pin 6) of IC1 and GND. IC1 has an internal pull-up current enabled on this pin which usually keeps it high, at around 5V. When S1 is pressed, this pin is pulled low to 0V, changing the digital input state, and this is sensed by IC1.

LED1 is used during setup and lights up when digital output GP5 (pin 2) is driven high. Its operating current is set to around 3mA by the 1kΩ series resistor ([5V - 2V] ÷ 1kΩ).

A 10kΩ pull-up resistor between pin 4 of IC1 (MCLR) and the 5V supply prevents unwanted resets of the micro. Its internal power-on reset circuitry ensures it starts up normally each time power is applied.

Construction

The Dimmer Adaptor is built on a double-sided PCB coded 05107191 which measures 77 x 47mm. This is sized to mount into a UB5 Jiffy box. The PCB overlay diagram shown in Fig.3 indicates which components go where.

Start by fitting the smaller resistors. Their colour codes are shown in the parts list but it's best to use a digital multimeter to double check their value as the colour bands can be easily misread.

Once all the smaller resistors are in place, mount zener diode ZD1 with its cathode stripe facing as shown, then the larger 470Ω 1W resistor.

Next, solder IC1's socket in place, followed by IC2. While you could use a socket for IC2, it's better to solder it directly to the PCB. Take care with the

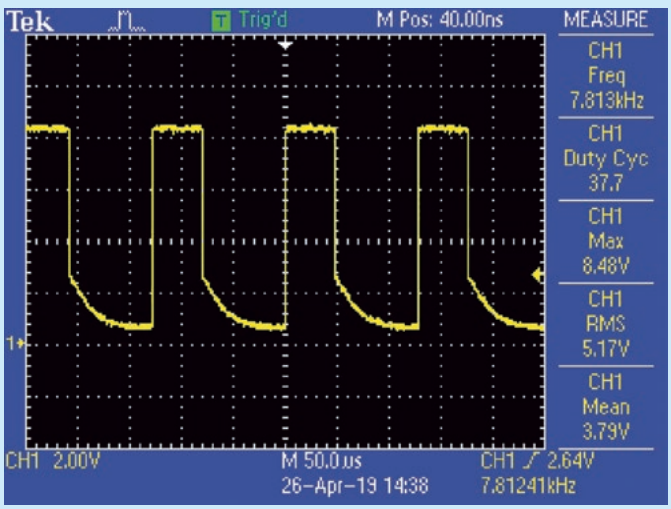


Fig.4: as described in the text, the unit can optionally control the head unit display brightness using PWM at 7.8kHz. This may give better brightness matching between different display elements. This shows a typical output waveform (at DIM OUT) when the Dimmer Adaptor is used in this manner.

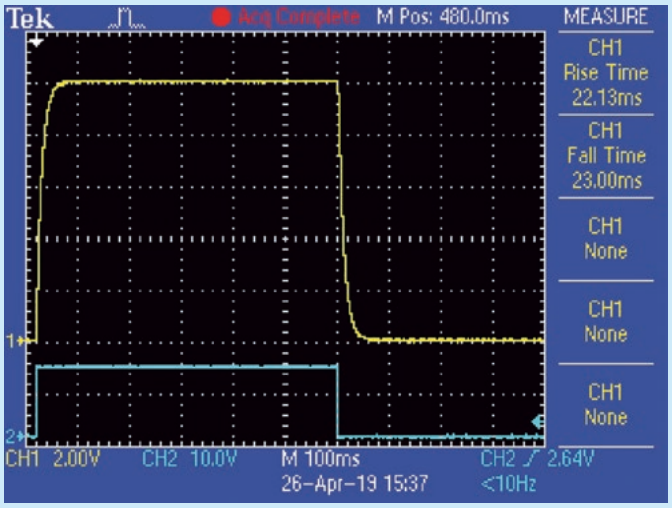
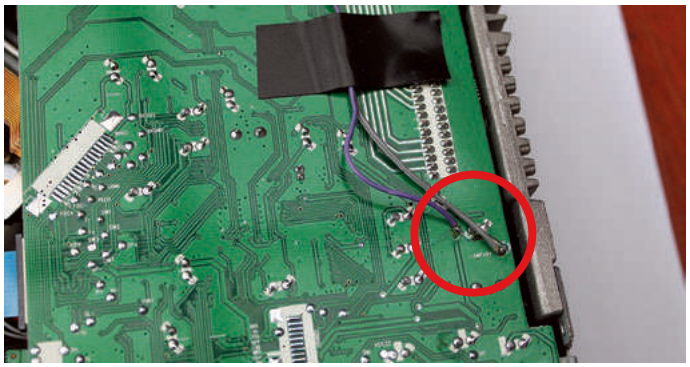
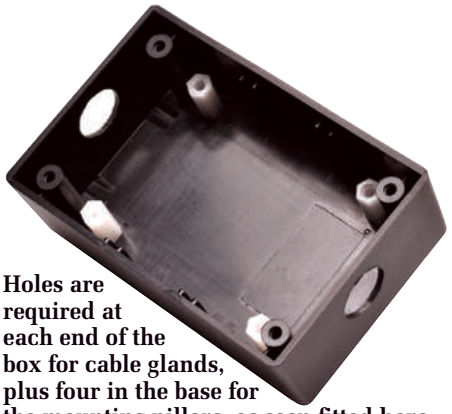


Fig.5: with VR1 set for 0-1V at TP2, the unit is in fast response mode. The cyan trace at the bottom shows a 12V step the input voltage, and you can see that the DIM OUT voltage (yellow) responds almost immediately, giving a response time of around 20ms, which is virtually unnoticeable.



The track feeding power to the head unit front panel display lighing has been cut and wires soldered to either side, run to the V+ and OUT terminals of CON2 on the Dimmer Adaptor.



Holes are required at each end of the box for cable glands, plus four in the base for the mounting pillars, as seen fitted here.

orientation of both and be careful not to mix up the two ICs as they both have eight pins. Follow with tactile switch S1, which will only fit with the correct orientation. Make sure it's pushed down fully before soldering its pins.

REG1 can be now installed. It is mounted horizontally on the PCB. Bend its leads so they enter the PCB pads with the tab mounting hole lining up with the hole on the PCB. Secure it to the board with a 6mm M3 screw and nut before soldering the leads.

Q2 also mounts horizontally, with its metal tab facing upwards. Secure it to the PCB using a 10mm screw and nut before soldering its leads

The smaller MKT capacitors are next; these are not polarised. Follow by mounting transistor Q1. Gently bend its leads to fit the hole pattern on the PCB, then solder it with its flat face orientated as shown in Fig.3.

Now fit trimpot VR1. It is 10kΩ and may be marked as either 10k or coded as 103. It is orientated with its adjustment screw toward LED1 (see Fig.3).

Once that is in place, fit LED1. Its anode (longer lead) goes into the pad marked "A" on the PCB. Install it with its lens about 5mm above the PCB, so its upper surface is level with the top of VR1.

The next job is to fit CON1 and CON2. CON2 can either be one four-way terminal block, or two 2-way terminal blocks dovetailed together.

In both cases, make sure the wire entry holes are facing towards the nearest edge of the board and that the blocks are pushed down fully before soldering their pins.

Now mount the polarised electrolytic capacitors. In each case, the longer lead goes into the pad marked with a + sign.

Housing

The Dimmer Adaptor could be fitted inside the head unit if there is room. Otherwise, you can mount it outside the head unit in a UB5 box. We used a flanged box that has an extended length lid with extra mounting holes, making it easier to mount under the dashboard.

But you can use a standard UB5 box instead, or the unit can be wrapped in insulation and cable tied in position.

To prepare the box, you need to drill holes for the cable glands at each end. There are cut-outs in the PCB to accommodate the gland nuts but note that the nuts need to be centred properly and orientated so that the sides are vertical to fit into these recesses.

Having fitted the cable glands, slide the PCB into place and mark out the four mounting holes, then drill them to 3mm. Mount the PCB using the four 12mm tapped spacers and eight machine screws.

If you want to make a label for the lid. The artwork can be downloaded from the SILICON CHIP website.

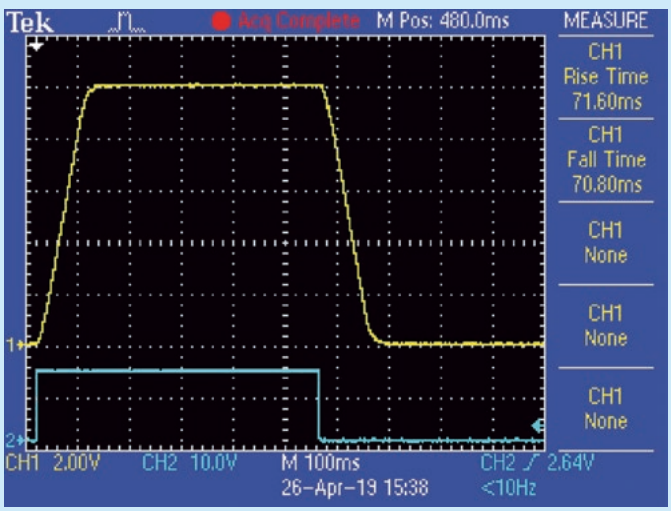


Fig.6: with VR1 set for 1-2V at TP2, the unit is in intermediate response mode. Once again, the input (cyan) has a 12V step, and the output is shown in yellow. Note the smoother output ramp and the response time of around 70ms. This will better match the response time of small incandescent lamps.

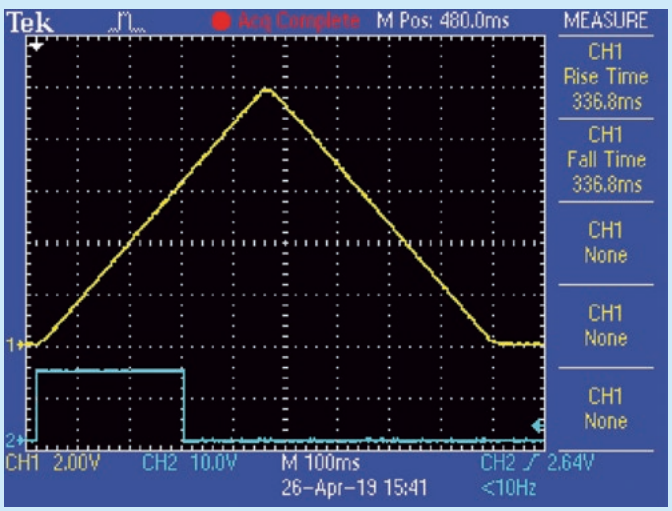
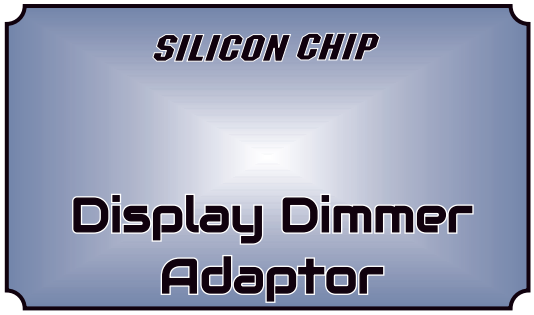


Fig.7: setting VR1 for more than 2V at TP2 gives an even slower response (proportional to the voltage). Here we have set 4V at TP2, giving about 1/3 of a second between the input changing and the output voltage reaching its target value. The maximum delay is 400ms with TP2 at 5V.



This front panel artwork can be photocopied or, for a better result, downloaded from siliconchip.com.au/shop/11/5061 and printed – see the text below for details.

For a rugged label, print onto clear overhead projector film (using film suitable for your type of printer) as a mirror image, so that the ink is on the back of the film when the label is affixed. Attach it with clear silicone sealant (or grey if the box is black).

Alternatively, you can print onto an A4 sized synthetic 'Dataflex' sticky label for inkjet printers or a 'Datapol' sticky label for laser printers.

For details see: **siliconchip.com.au/Help/FrontPanels**

Installation

The Dimmer Adaptor is supplied with power from the vehicle's ignition-switched +12V wire plus a chassis connection for 0V. (Power could also be supplied from the head unit "power antenna" wire which is live when the ignition is switched on).

Both of these wires are accessible at the rear of the head unit. Just make sure the +12V wire you tap into is off when the ignition is off.

The vehicle's instrument light dimming wire then needs to be connected to the Dimmer Adaptor input (labelled "IN" on CON1). That takes care of the three wires to CON1.

To make the connections to CON2, you will also need to delve inside the radio head unit and find the main supply for its display lighting. You can do this using a multimeter.

Most aftermarket head units have a detachable front panel and the power for the panel backlighting is fed to it via a multi-pin connector, so you can find the backlighting power pins by probing these pins.

Set your multimeter to its 20V range (or slightly higher, if it doesn't have a 20V range) and connect the black probe to chassis or some other convenient 0V point.

Probe the head unit front panel pins, looking for a steady reading of around 7-10V.

Our test head unit was marked as 9V, but we found that this was closer to 8V. This is the positive rail for the display lighting.

Once you've found it, you need to open up the head unit itself and break the PCB track feeding this pin; it will likely come from the output pin of a regulator before going to the front panel connector.

Confirm you have the right track with a continuity measurement before cutting.

The Dimmer Adaptor V+ terminal on CON2 goes to the regulator output (ie, the driven side of the cut track), while the DIM OUT terminal is wired to the section of the cut track going to the front panel. The earlier photo shows where we made our connections.

Note that while we have used tape as a temporary measure to support the wires, it will not hold for long. We recommend using dabs of neutral cure silicone sealant (eg, roof and gutter sealant) to hold the wires permanently and secure in place.

You can run these two wires out of a pre-existing hole on the head unit, or if there is no suitable hole, drill one. You can seal it up with another squirt of silicone, and this will also prevent the wires from chafing or doing any damage if they are bumped or pulled.

Checking the dimming signal

The unit controls the radio lighting to follow any curve within the voltage range of the circuit (0-15V). Basically, you are defining a mathematical function (curve) which maps the incoming voltage from the vehicle dimming circuitry to the output voltage, which controls the head unit brightness.

Before going any further, connect your DMM (still on a low DC volts range) between TP1 and GND and verify that the voltage varies as you adjust the vehicle's instrument dimming control.

You should get a varying reading on your meter regardless of whether the vehicle's dimming is linear or PWM-based. Note though that if the vehicle's dimming is PWM based and uses a frequency well below 100kHz, you may need to increase the value of the 100nF capacitor connected to pin 3 of IC1 (in the lower left corner of the PCB) to give smooth dimming.

For example, you could use a 10µF electrolytic capacitor if you find your vehicle uses 1kHz PWM (positive to the top) or 100µF for a 100Hz PWM frequency. Many multimeters have a frequency measurement function, so it's a good idea to check the dimming frequency now.

Set-up procedure

The unit needs to be calibrated to provide an appropriate light output from the head unit over the vehicle's instrument dimming range. In other words, we want its brightness to match that of the other instruments as they are dimmed. Entering set-up mode clears any previous configuration. So the unit needs to be set up from scratch each time.

The set-up procedure is best done when it is dark; if you have a garage, you can sit in the car with the door closed and the lights off. Otherwise, you will need to wait until night time.

To enter the programming mode, press and hold S1 as you are switching the ignition on.

(Note: you don't need to start the engine and indeed, if you are in a garage or other confined space, you should not do so.)

When you release S1, LED1 will flash once to indicate that the Dimmer Adaptor is ready to be set up. Switch on the radio head unit and turn on your parking lights or headlights, then set the dash lights to their highest brightness.

The unit is set up by successively dimming the dashboard lamps using the vehicle's dimmer, then adjusting VR1 on the unit to give a similar brightness on the radio head unit. S1 is then pressed to store this data point. Several different levels can be programmed, and the micro then generates a piecewise linear curve by interpolating between each step.

The input voltage must start at the highest voltage and progressively drop for each successive voltage point that is saved. This is why you need to set the dash lights to maximum brightness to start.

Adjust VR1 to give the desired head unit display brightness to match your maximum brightness instrument lights. Then press S1. LED1 should flash off twice, indicating the next value to be programmed is at point 2.

Then dim the instruments a little and adjust VR1 for a similar dimming on the head unit. Press S1 to program it in.

You can program up to 16 brightness values, although you don't have to program that many.

One thing to keep in mind during the set-up procedure is that you probably want the head unit display to operate at full brightness during the day, when your headlights (and thus instrument lights) are off. When this is the case, there will be no voltage at the unit's input.

So once you have reached minimum instrument brightness, switch off the lights and adjust VR1 to maximum (or your desired display brightness setting for daytime use) and press S1 to set the final stored value for this situation.

Once you've finished programming in all the brightness steps, switch off the ignition. When you switch it on again, without pressing S1, the Dimmer Adaptor will dim the head unit display as programmed, and provide full brightness when the parking or headlights are off.

Switching to PWM control

If you find that some of the display LEDs do not dim to the same level as others, or the alphanumeric display does not dim at a similar rate to the switch illumination LEDs, it may be that there are fewer or more LEDs connected in series, causing the mismatch in brightness with dimming voltage.

This can be cured by converting the Display Dimmer Adaptor to produce a variable duty cycle switch mode output drive to the radio head unit display panel instead of a DC voltage, as explained above in the circuit description. Having made this change, you will need to repeat the setup procedure, but otherwise, the unit will operate in substantially the same manner.

Making these changes is easy. Cut the thin track on the bottom of the PCB, between two rectangular blocks, near the MOD terminal of CON2 (shown as a red line in Fig.3). Then solder a component lead offcut between the two nearby empty pads, shown as a red line in Fig.3. Finally, remove the 100nF capacitor below REG1 and immediately to the left of the 3.3kΩ resistor, and the 10µF electrolytic capacitor.

Fig.4 shows a typical waveform at the DIM OUT terminal of CON2 when the unit is operating in PWM mode.

Using VR1 to adjust dimming speed

Once the unit has been set up, trimpot VR1 can then be adjusted to give either fast, smooth or delayed dimming of the head unit display.

The main reason for providing these options is so you can have the head unit display dimming match the brightness of incandescent lamps that may be used in the instrument cluster. These can take time to change brightness due to thermal inertia in the lamps.

Each time you adjust VR1, press S1 to have this new adjustment take effect. LED1 will light to indicate that VR1's position has been read.

Note that you don't have to press S1 if you adjust VR1 when the unit is off, as VR1's position is read at power-up.

When VR1 is adjusted so that the voltage at TP2 is below 1V, the unit will adjust its output brightness as soon as it notices a change in the input voltage, giving virtually no delay. This is demonstrated in Fig.5.

When VR1 is set for a voltage of 1-2V at TP2, the output voltage will change more smoothly and more slowly. In this mode, the output changes in small increments over time until it reaches the required voltage; see Fig.6.

This rate is even slower if VR1 is adjusted for 2-5V at TP2, as shown in Fig.7. SC

Using this unit as a Voltage Modifier

The separate output at CON2 labelled MOD OUT allows the Dimmer Adaptor to be used as a voltage modifier. So if you have a sensor output that varies over a specific voltage range, but want to change that range (eg, to suit an ECU which expects a different type of sensor or to change a vehicle's throttle response), you can use this design to do just that.

There are many automotive uses for a Voltage Modifier. As this unit lets you program the output voltage for a series of different input voltages, and then linearly interpolates between them, you can build up an input/output voltage map quite easily.

If you need a more comprehensive and fully featured Voltage Modifier, then see our Automotive Sensor Modifier design in the December 2016 issue (siliconchip.com.au/Article/10451).

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Quantum-dot Cellular Automata

For almost forty years now, CMOS has been the technology of choice for implementing digital logic. And over that time, transistors have consistently shrunk, allowing higher logic density, faster operation and lower power consumption. But further improvements are becoming increasingly challenging. Quantum-dot Cellular Automata technology could provide a quantum leap (no pun intended) in logic performance.

Virtually all digital chips these days are built using Complementary Metal Oxide Semiconductor (CMOS) technology. This is a mature technology, with many advanced fabrication facilities worldwide churning out large numbers of high-performance microprocessors. But it is becoming increasingly difficult to improve this technology.

To gain better performance, CPU fabrication processes need to achieve faster switching speeds, lower leakage currents, higher density, lower power consumption (and thus heat generation) and all this while keeping reliability high and costs low.

Quantum-dot Cellular Automata (QCA) is one of the most likely technologies to succeed CMOS. Other possibilities which are currently being investigated include the Single Electron Transistor (SET) and Carbon NanoTube Field Effect Transistor (CNTFET).

QCA is an emerging concept in computational nanotechnology. QCA cells can be used to perform all complex computational functions essential for general-purpose computation. This includes the majority function (the output value is the mode of the input values, ie, if more than half the cells are logic high than the output will be a logic high), inversion (an input of 1 becomes an output of 0, and vice versa) and fan-out (the output of one cell feeding multiple inputs).

QCA technology may replace CMOS technology in the near future because it can be fabricated with tiny cells (on the nanometre scale) which can provide high density, and it offers the possibility of high operational speeds – into the terahertz range! It also has ultra-low power consumption, without any leakage currents at the nanoscale level.

The biggest challenge at the moment is finding suitable QCA chip fabrication techniques which can be implemented on an industrial scale.

This article describes the basic principles of using QCA technology to implement logic functions in an integrated circuit.

Basics of QCA technology

The QCA cell is the fundamental component in QCA technology. It comprises four quantum dots which are connected through electron tunnel junctions – see Fig.1(a).

There are four places where electrons can conform inside the cell, but only two electrons are trapped inside. These electrons will take residence in the two locations which require minimum energy (ie, place the cell in its lowest stable energy state), for example, as shown in Fig.1(b).

To be in a low energy state, the two electrons must be at the furthest possible distance apart, which means that they will reside in opposite corners of the cell. Coulomb interaction between electrons in adjacent cells (in this case repulsion) is used to gain the necessary computing logic states like logic zero and logic one. The two possible states are shown in Fig.1(c), and they are arbitrarily assigned to represent zero and one.

The logic state passes from one cell to another nearby due to the electric field interactions of the electrons in the wells. Cell polarisation propagates through all nearby cells and continues all over the circuit until it reaches the end.

By Dr Sankit Ramkrishna Kassa, SNDT Women's University, Mumbai, India

Image source: *https://softologyblog.wordpress.com/2016/11/17/more-experiments-with-coupled-cellular-automata/*

Because of these interactions, no current flows between the cells; the electrons only move within the cell, and as they move in opposite directions, their magnetic fields cancel out (as do their electric fields, except at very short distances from the cell). Therefore, very little power is consumed by QCA circuits when transitioning from one logic state to another.

Fig.2 shows the structure of a QCA wire, used to pass information. The cells are simply arranged side-by-side. Right-angle turns are possible, and logic signals can be distributed by T-intersections (fan-out) or even X-intersections.

The resting state of each cell in the wire is the same (one or zero) because electrons repel each other, as they are negatively charged, and this allows the electrons to remain as far apart as possible. As mentioned above, this is the lowest stable energy state.

One end of the wire is actively driven, either from an external signal or by another QCA cell which is being held in a particular state, and the signal propagates along the wires as each cell moves into its lowest energy state, ie, aligned with the other cells. Propagation speed and direction are controlled by choosing which cells are on which clock phase, which is explained later in more detail.

Fig.3(a) shows how a logic inverter can be formed from QCA cells. Essentially, it's just two wires which meet at one corner. Once again, the electrons re-arrange themselves to be as far apart as possible, but in this case, that happens when the logic values in the output wire are the opposite of those in the input wire.

Note that it's easier for us to show cells diagonally opposite each other, but in reality, there would probably be a slight overlap to enhance the electric field interactions of the electrons in the corners.

Note also that the actual fabricated cells will not necessarily be square; if they have rounded or cut-off corners, that would allow the electrons to be closer again.

The inverter shown in Fig.3(b) works in the same manner, but because the input wire splits, its electrons can be in proximity to two corners of the first cell in the output wire, doubling the interaction between them and making the result both faster and more reliable.

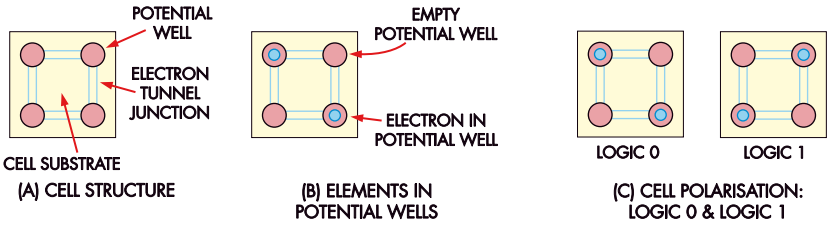


Fig.1: a quantum cell consists of two electrons located in four possible wells, joined by four tunnel junctions. The electrons tend to reside in diagonally opposite wells as this is the lowest energy state. The two resulting possible states are defined as logic one and zero.

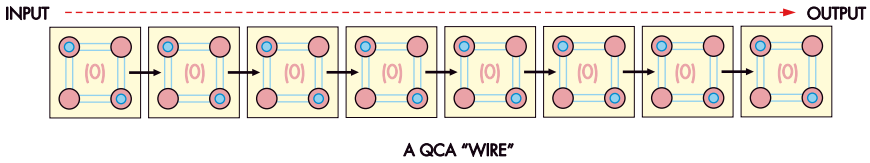


Fig.2: the logic state propagates along a QCA wire consisting of several cells placed side-by-side, due to the repulsion of the electrons in adjacent cells. They will stabilise at the greatest distance possible, which is where all cells are either in the zero or one state.

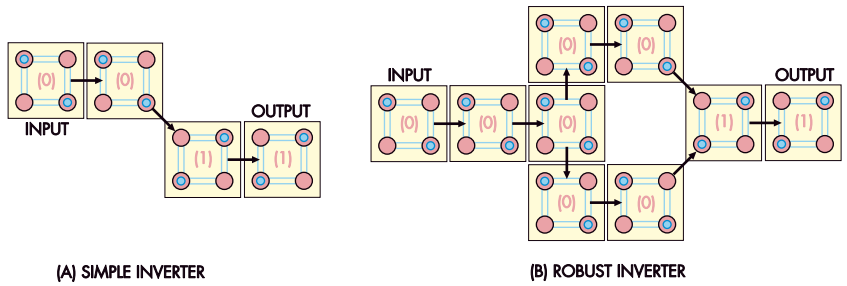


Fig.3: an inverter is formed by placing two QCA wires in contact at their corners. The lowest energy state in this configuration is with all the cells in one wire in one state, and the cells in the other wire in the opposite state. This can be doubled-up to make a more robust but functionally equivalent inverter.

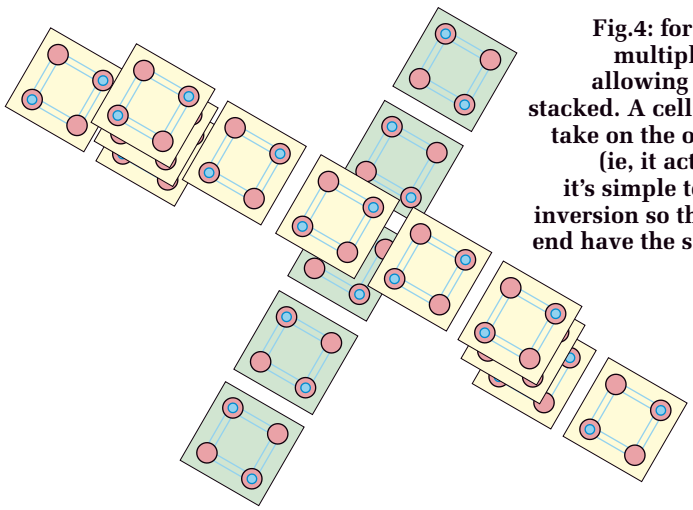
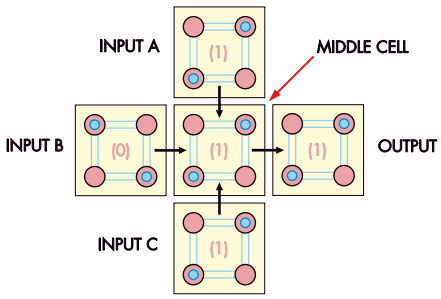


Fig.4: for QCA wires to cross, multiple layers are needed, allowing cells to be vertically stacked. A cell above or below will take on the opposite polarisation (ie, it acts as an inverter) but it's simple to arrange for double inversion so that the cells at either end have the same polarisation, as shown here.

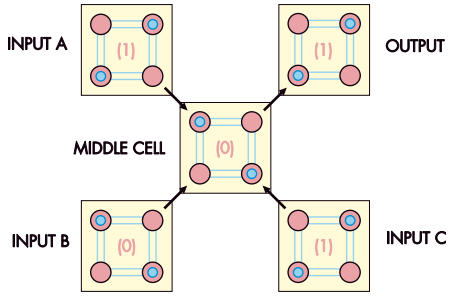
Cells can also be stacked vertically, to form 3D structures, so that wires can cross. Fig.4 is an orthographic projection of two wires crossing, with different logic polarisations. Note that each QCA cell stacked vertically above another effectively forms an inverter. But so long as the number of inverters in each wire is even, the states at either end will be consistent.

Building logic with QCA cells

The most fundamental structure in QCA logic is the three-input majority gate, shown in Fig.5(a). All other logic structures such as AND gates, OR



(a) A 3–INPUT MAJORITY GATE



(b) ALTERNATIVE 3–INPUT MAJORITY GATE

Fig.5: the 3-input majority is the most fundamental logic gate used in QCA logic. This shows two possible implementations of the gate, functionally identical but with the inputs and outputs arranged differently. Any of the four surrounding cells can be the output; this is determined by which cell is free to change state (ie, is not actively driven) and the three inputs are interchangeable.

gates, XOR gates, adders, multiplexers etc are usually formed from this arrangement.

Once again, it works because the cells settle in the lowest possible energy state. When all three input cells have the same state (all zero or all one), the middle cell aligns with the others, and thus so does the output – and the polarity of all the cells becomes the same.

But when one of the input cells is in a different state from the other two, its effect on the state of the middle cell is weaker, as the electric field acting on the middle cell is the combination of the three external fields. And since the electrons can only exist within the wells (based on quantum theory), they will settle in the wells which are on average furthest from the others nearby.

Therefore, when two of the inputs are one and one is zero, the middle cell and the output are one, and when two of the inputs are zero and one is one, the middle cell and output settle at zero. Hence, we get our 'majority out of three' effect.

Given that the structure is symmetrical, how do we determine which cells are the inputs (which are functionally interchangeable) and which is the output? It merely depends on which cells are being actively driven. The three inputs are driven externally or from the 'outputs' of other wires/structures, while the output cell is free to take on either state, and can then go on to influence other cells.

The arrangement shown in Fig.5(b) has the same effect as that of Fig.5(a), working on the same principle, except that the electrons interact in the corners rather than along the edges of the cells. There are some logic structures where this configuration would fit better. Note that the middle cell's polarisation is opposite to that shown in Fig.5(a), but this is re-inverted at the output, so is of no consequence.

Forming the usual logic gates

Fig.6(a) shows how an OR logic gate is formed from a 3-input majority gate, by changing one of the three input cells to a cell which has its value fixed at one.

This would generally be built using a normal cell, but having an external electric field (eg, from a nearby conductor held at a particular potential) which forces it to remain in this particular state permanently. It might also be built by doping the cell in such a way that it only has two wells.

So now, we have the situation where we only need one of the two inputs to be a one before the majority of inputs are one, and thus the output is one – which is, in effect, the OR function. In other words, the output is one unless both input values are zero.

The AND gate shown in Fig.6(b) is made in the same way, except now the fixed cell has a value of zero. So for the output to be one, both inputs must have a value of one.

Building an XOR gate is a little more complicated. Fig.7 shows how three AND gates, an OR gate and an inverter (to turn the AND gate into a NAND gate) can be configured to form the XOR function. And Fig.6(c) shows this same structure implemented using QCA.

You should be able to identify the AND gates, OR gates and inverter by comparing sections of Fig.6(c) with Figs.6(a) & (b) and Fig.3(a). But in case it isn't clear, we've labelled the gates for you, and colour-coded the cells. External inputs are shaded green, outputs blue, inverters red, fixed gates grey and 3-input majority gates orange.

Any logic structure can be built up from AND, OR and XOR gates, although with QCA, it's often easier to return to 'first principles' and use 3-input majority gates as the primary element, as this results in smaller and faster designs.

Other logic implementations

Because QCA cells interact by the electrons contained within repelling electrons in other cells, it is possible to design more complex QCA gates by taking advantage of the fact that cells not directly adjacent can still have some interactions.

In the designs described above, the interactions between adjacent cells dominate, and so cells further away have no real effect, except perhaps to slightly speed up or slow down the expected transitions. But say you have a cell with two adjacent cells, and those two cells are in opposite states, ie, one is zero and one is one.

Their electric fields would cancel out around the cell in question, so you would not know what state it would settle in. However, that may then be determined by the next closest set of cells. It is possible to take advantage of this to produce more compact implementations of certain sets of logic.

For example, Fig.6(d) shows an alternative XOR gate design. As you can see, it is much more compact than the 'obvious' design shown in Fig.6(c). The cells shaded in pink are synched to clock one, while those in yellow are tied to clock two (see below for an explanation of clocks). When the inputs are both zero or both one, you can follow the flow of logic through the gate using the rules described above and you get the right answer at the output (ie, zero in both cases).

However, it's not so straightforward when one input is zero and the other is one. In this case, the cell to the left of the output has a zero cell at one corner and a one cell at the other corner. So its state will depend on the states of cells further to the left.

One disadvantage of this approach is that this logic block may need to be clocked more slowly than the one shown in Fig.6(c) because it relies on a weaker interaction (the fixed cell

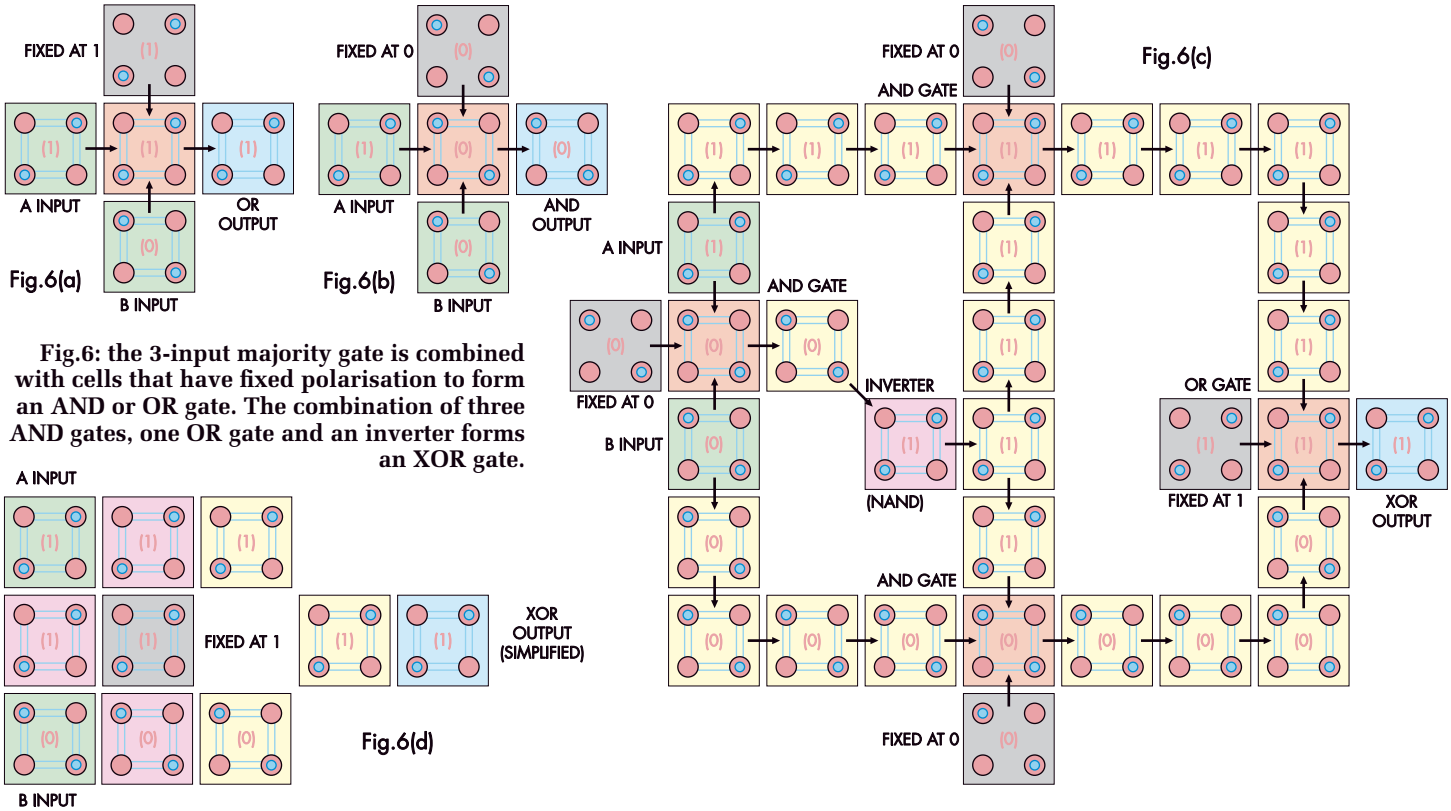


Fig.6: the 3-input majority gate is combined with cells that have fixed polarisation to form an AND or OR gate. The combination of three AND gates, one OR gate and an inverter forms an XOR gate.

interacting being the tie-breaker two cells away), and will take longer to settle into a steady state. On the other hand, it requires fewer clock phases from input to output, which could mitigate the slower clock requirement.

But until QCA logic is implemented successfully on an industrial scale, we won't know whether that speed impact negates the other advantages of such a configuration. There are many other possible XOR gate implementations and one of the other options may possess the best trade-off between size, delay and clock speed.

Clocking

All QCA circuits require a clock which most importantly provides power to run the circuit, as well as synchronisation and control over the information flow through QCA wires.

QCA logic normally uses four clocks, and each clock has four phases 90° apart. Each of the four clocks are 90° out of phase from the prior clock. This is known as Landauer clocking. The four phases are switch, hold, release and relax, as shown in Fig.9. The designer can choose which clock feeds which cell, and therefore, in which directions signals flow through the cells.

During the switch phase, the QCA cells settle down to one of the two defined logic states, as influenced by its neighbours, some of which will normally be in the hold phase. During the hold phase, the QCA cells maintain their current state. During the release and relax phases, the QCA cells become unpolarised in preparation for the next switch phase.

Often, several adjacent cells run on the same clock, forming small static 'islands' through which information can propagate freely during the switch phase. Their states are locked together during the hold phase.

The clock phase relationship of cells is often shown through colour-coding, although we have avoided this in most of the earlier diagrams, as it can be confusing to beginners. However, choosing the right clock phase for each cell is very important, as depending on the design, changing a cell from one clock to another one can stop it from working properly.

Note the number of cells allowed on one clock must be <= $e^{E_k} \div (K_B \times T)$. Where E_k is the kink energy, K_B the Boltzmann constant and T is the operating temperature in Kelvins. The kink energy is the difference in energy between two cells with the same polarity and the opposite polarity.

A one-bit adder

To demonstrate building a more complicated (and indeed useful) logic block using QCA, we will now show how a one-bit adder can be formed. These can be daisy-chained to allow

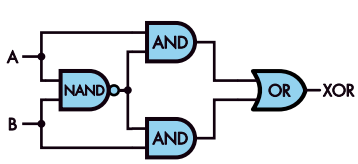
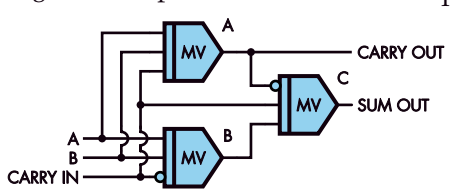


Fig.7: this shows how the XOR gate operates, based on other gates which are easier to build.



A	0	1	0	1	0	1	0	1
B	0	0	1	1	0	0	1	1
CARRY IN	0	0	0	0	1	1	1	1
SUM OUT	0	1	1	0	1	0	0	1
CARRY OUT	0	0	0	1	0	1	1	1

Fig.8: three 3-input majority gates plus two inverters can be used to build a one-bit adder with carry inputs and outputs. These can be easily combined to form multi-bit adders (eg, 16-bit, 32-bit or 64-bit).

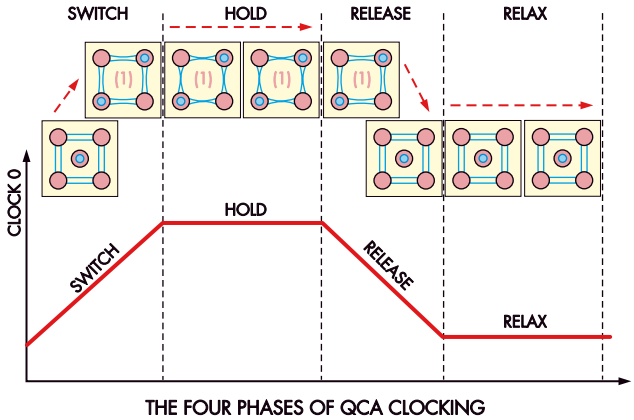


Fig.9: QCA logic uses a four-phase clock. During the switch phase, cells start unpolarised and begin to polarise while the tunnelling barrier is raised. In the hold phase, the barrier is raised high enough so that tunnelling cannot occur and the cell is locked to its current polarisation. In the release phase, the barrier is lowered and the cell returns to its unpolarised state. In the relax state, the cell remains unpolarised and thus is in a neutral or "ground" state (neither "0" or "1"). This neutral state is sometimes shown as a electron located in a fifth well in the middle of the four outer wells.

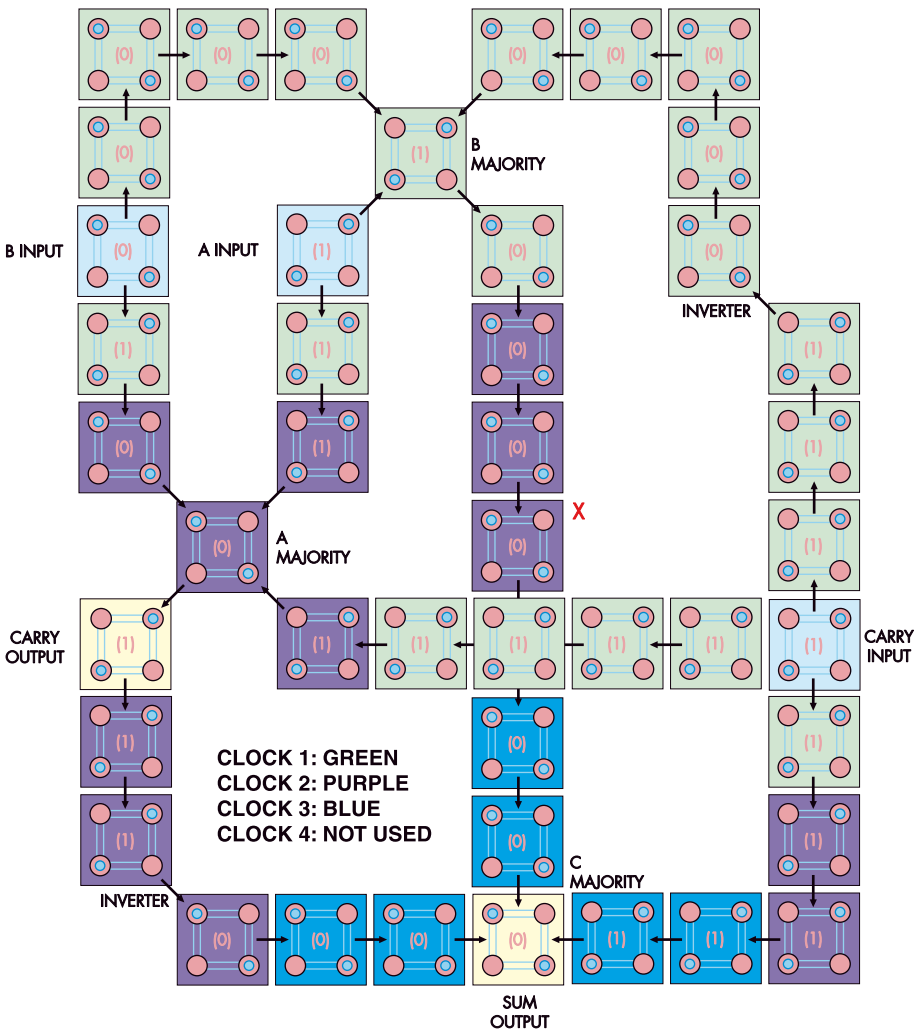


Fig.10: a practical implementation of the one-bit adder using QCA cells. You can see how the three majority cells correspond to Fig.8 by the A/B/C labelling. One problem with this adder that the A input is located inside the circuit. Also note that due to the way it is clocked, the series of cells that come from the B majority actually skips over the cell in the intersection. This is because when the cell marked "X" is in the hold phase, therefore polarised, the green cell directly below it will be in the release phase (unpolarised) and have no effect on the blue cell below. This means that during the switching phase, the blue cell will primarily be affected by cell X two cells above it.

larger numbers to be added.

For example, 32 one-bit adders form a single 32-bit adder, capable of summing two integers between 0 and 4,294,967,296 (ie, a little over four billion), or between -2,147,483,648 and +2,147,483,647.

That isn't to say that using 32 one-bit adders is necessarily the best way to add two 32-bit numbers, but it will undoubtedly give you the right result.

The basic concept of how to form a one-bit adder using QCA is shown in Fig.8, along with its truth table. "A" and "B" are the two numbers to add up (either zero or one), and "CARRY IN" is the carry output of the previous stage, which is usually fixed to zero for the first stage. The result is a two-bit number, represented as "SUM OUT" (the lower bit) and "CARRY OUT" (the upper bit).

As you can see, the one-bit adder function can be formed from three 3-input majority gates (labelled "MV" for "majority vote") and two inverters, shown as circles at two of the gate inputs.

One possible QCA implementation of this logic configuration is shown in Fig.10. The colour coding this time shows the clock phases for each cell. One critical part of this circuit is the placement of the clocks as it helps control the flow of logic.

Note that the distance between outputs, inputs and computational cells is critical, due to unintended interations between cells if they are moved to slightly different positions.

Therefore, designing QCA logic is a bit more tricky than implied by our description so far, and assigning clock phases correctly to cells each cell is also vital, giving them time to stabilise in the correct polarity. It's also important to avoid having too many or too few cells on the same clock, depending on the clock timings that will be used.

One potential problem with this circuit is the location of one of the inputs, as it is surrounded by the circuitry. This means multiple layers would be required to provide input data. This makes it more difficult to expand to form a multi-bit adder, however, this example circuit is much simpler than other arrangements.

If you follow the signal flow, represented by the small black arrows, you will see that this arrangement calculates the logic exactly as shown in Fig.8. The cell states are shown for

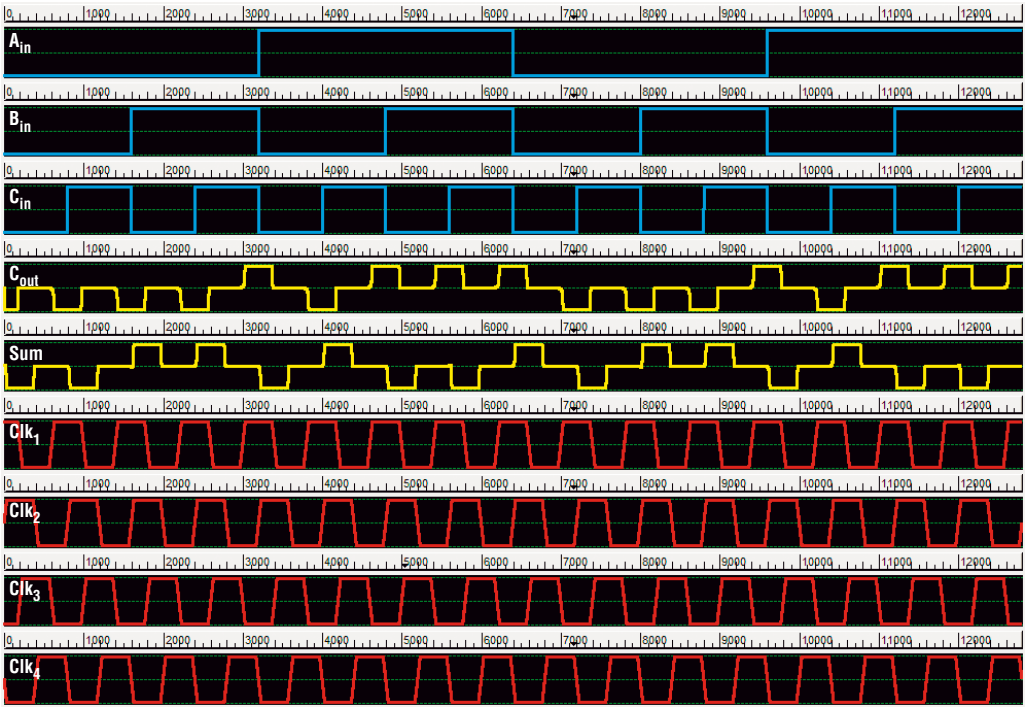


Fig.11: input, output and clock waveforms for the one-bit adder as simulated by QCADesigner. Shown from top-to-bottom are inputs A, B and the Carry Input, then the Carry and Sum Output followed by Clocks 1-4. Note that the Carry Output is on Clock 1 so it appears 90° earlier than the Sum Ouput on Clock 2. Note that the output for the first values of the simulation are not always accurate.

the case where A=1, B=0 and CARRY INPUT=1, giving the correct result of SUM OUTPUT=0 and CARRY OUTPUT=1.

Fig.11 shows the simulated waveforms from the one-bit adder shown in Fig.10, once the four clocks have been applied as required for each cell. Note how the outputs swing between ±1V, but are close to 0V during the release and relax phases. The outputs should be sampled during the hold phase to ensure valid data is received.

The QCADesigner tool

If you would like to try your hand at designing QCA-based logic, you can try out QCADesigner. This is a free, open-source tool which is available online at: https://waluslab.ece.ubc.ca/qcadesigner/

It facilitates design, layout and simulation of QCA circuits. The user can quickly lay out a QCA design with an extensive set of CAD tools. Several simulation engines allow rapid and accurate simulation. This tool has been used by researchers to design full adders, barrel shifters, random-access memory, etc.

Editor's Note: sometimes simulation using QCADesigner can be inconsistent. We've found that the first and last values will differ between runs on some circuits and are best ignored.

QCA chip manufacturing

There are four types of fabrication classes defined for QCA IC manufacturing: semiconductor, molecular, metal-island and magnetic.

a) Semiconductor: the existing, highly advanced CMOS manufacturing technology can be used to fabricate QCA cells. Cell polarization is encoded as charge position, and quantum-dot interactions rely on electrostatic coupling. But with current CMOS technology, only small numbers of cells can be fabricated at a nano-scale level.

b) Molecular: a fabrication method to build QCA cells from single molecules. Its advantages include: highly symmetric QCA cell structure, very high switching speeds, extremely high device density, operation at room temperature, and even the possibility of mass-producing devices using self-assembly.

c) Metal-island: the first technology that has been used to demonstrated QCA operation in the real world. Quantum dots are built using aluminium with metal islands as big as 1 micrometre in dimension. The problem with this is that the cells are too large to be truly competitive with CMOS. For that, QCA needs to reach the nano-scale level. Also, metal islands that large require extremely low temperature for correct operation.

d) Magnetic: also referred to as MQCA, is the latest trend in QCA fabrication. Here, the interaction between magnetic nanoparticles provides the two polarities. The magnetisation vector of these nanoparticles is analogous to the polarization vector in all other implementations.

In MQCA, the term 'quantum' refers to the quantum-mechanical nature of magnetic exchange interactions and not to electron-tunnelling effects. Devices fabricated this way can operate at room temperature.

Conclusion

If nano-scale QCA-based ICs can be mass produced, it will have a huge impact worldwide and completely change the electronics industry. Powerful chips will become tiny and operate at extremely high speed with very low power consumption.

This will have an especially big impact on the following industries: military, security, communications, gaming, artificial intelligence, autonomous vehicles and chip design.

The power needs are projected to be so low that QCA devices will be able to power themselves using solar cells integral to the chips.

More information

The links below should explain QCA in greater detail:

siliconchip.com.au/link/aaqg
siliconchip.com.au/link/aaqh
siliconchip.com.au/link/aaqi
siliconchip.com.au/link/aaqj
siliconchip.com.au/link/aaqk
siliconchip.com.au/link/aaql

SC

LFSR Random Number Generator Using Logic ICs

By combining just a few logic ICs, it is possible to digitally generate a pseudo-random number sequence. There are two reasons why you might want to build this circuit: one, it's interesting and will help you learn how logic ICs work. And two, it can do something useful: it can generate LED patterns to display on our very popular Stackable LED Christmas Tree that we published in November last year.

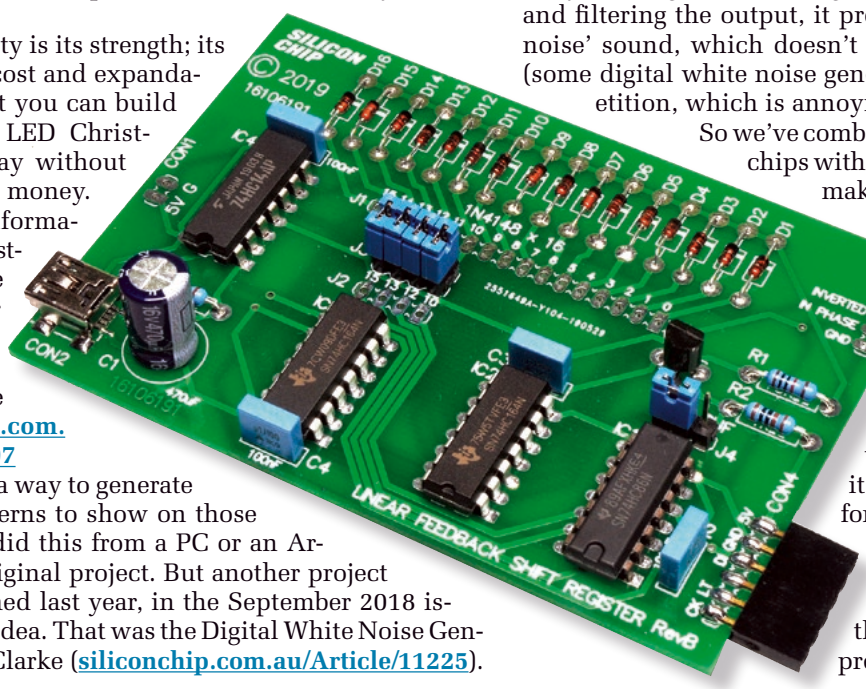
by Tim Blythman

The LED Christmas Tree is electrically quite simple: it takes a DC power source and a serial data stream, and switches the dozens or even hundreds of LEDs on and off to create the pattern that's described by that serial data.

This simplicity is its strength; its low per-board cost and expandability mean that you can build an impressive LED Christmas Tree display without spending much money.

For more information on that Christmas Tree, see the November and December 2018 issues or visit our website at: siliconchip.com.au/Article/11297

You do need a way to generate interesting patterns to show on those LEDs, and we did this from a PC or an Arduino in the original project. But another project that we published last year, in the September 2018 issue, gave us an idea. That was the Digital White Noise Generator by John Clarke (siliconchip.com.au/Article/11225).



In that article, John programmed a small microcontroller to produce a seemingly random (but not quite) series of 1s and 0s that would not repeat until about four billion cycles.

By running this random generator at quite a high speed, and filtering the output, it produces a convincing 'white noise' sound, which doesn't repeat for a very long time (some digital white noise generators have noticeable repetition, which is annoying!).

So we've combined a couple of shift register chips with a few other bits and pieces to make a similar random number generator without using a microcontroller. And we've made it so that you can use it to drive the LED Christmas Tree, or just as a way to investigate and understand its principle of operation. It's nice and simple, so it's easy to build and straightforward to understand.

We describe it as "pseudo-random" and not truly random because if you know the current state, you can predict the next state, and the

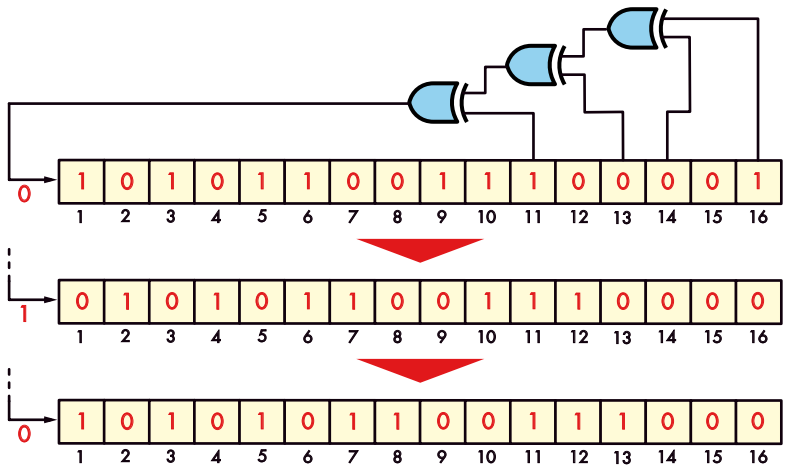


Fig.1: this shows one way of building a 16-bit LFSR with a maximum non-repeat interval of 65,535 clocks. It's a relatively simple method, so it's the one we've chosen to use in this project. The binary values in each cell move one step to the right in time with the clock signal. The XOR gates calculate a new bit value which is fed in as the first bit of the sequence. Three iterations of the pattern are shown.

pattern does eventually repeat. But in practice, the outputs change so fast that the output is not really predictable and the repetition period is long enough that you're unlikely to notice it.

The computations needed to generate this random string of binary digits are quite simple. This is a technique known as a Linear Feedback Shift Register (LFSR), but note that the word "linear" is not used here in the electronic sense – we'll have more on that shortly. That means that you don't necessarily need a microcontroller to use this technique. Old-fashioned discrete shift registers can do the job, too.

Shift register basics

Fig.1 shows how a shift register works. Data is fed into one end of the shift register, and on each clock pulse, that value (zero or one) is loaded into the first position in the shift register. The data which was previously in the first position then moves into the second position, and so on until the last value which used to be in the last position 'falls out' and may go on to be used elsewhere, or is simply discarded.

Some shift registers also include an output latch, so that you can shift all new data into the register without the output states changing, and the new data is then fed through to the output latches when a separate clock pin is pulsed. We don't need that sort of function in this project, though; the shift register ICs we're using update their output states the instant that they receive a clock pulse.

Generating random numbers

The idea behind the LSFR is to feed back the data which is about to 'fall out' of the end of the shift register back to the input side. But it isn't fed back as-is, because if it was, the pattern would repeat every eight cycles for an 8-bit register, or 16 cycles for a 16-bit register etc. That's far too predictable to be considered random.

However, if the data coming out of the shift register is combined with the state of some of the bits already in the shift register, even in a very simple way, that prevents the pattern from repeating until a much larger number of steps have occurred.

In our circuit, we have combined two 8-bit shift register ICs to form a single 16-bit shift register. The aforementioned White Noise generator used a 32-bit register which gave a much longer repeat period; however, being implemented in software using a microcontroller, those extra bits didn't take up physical space.

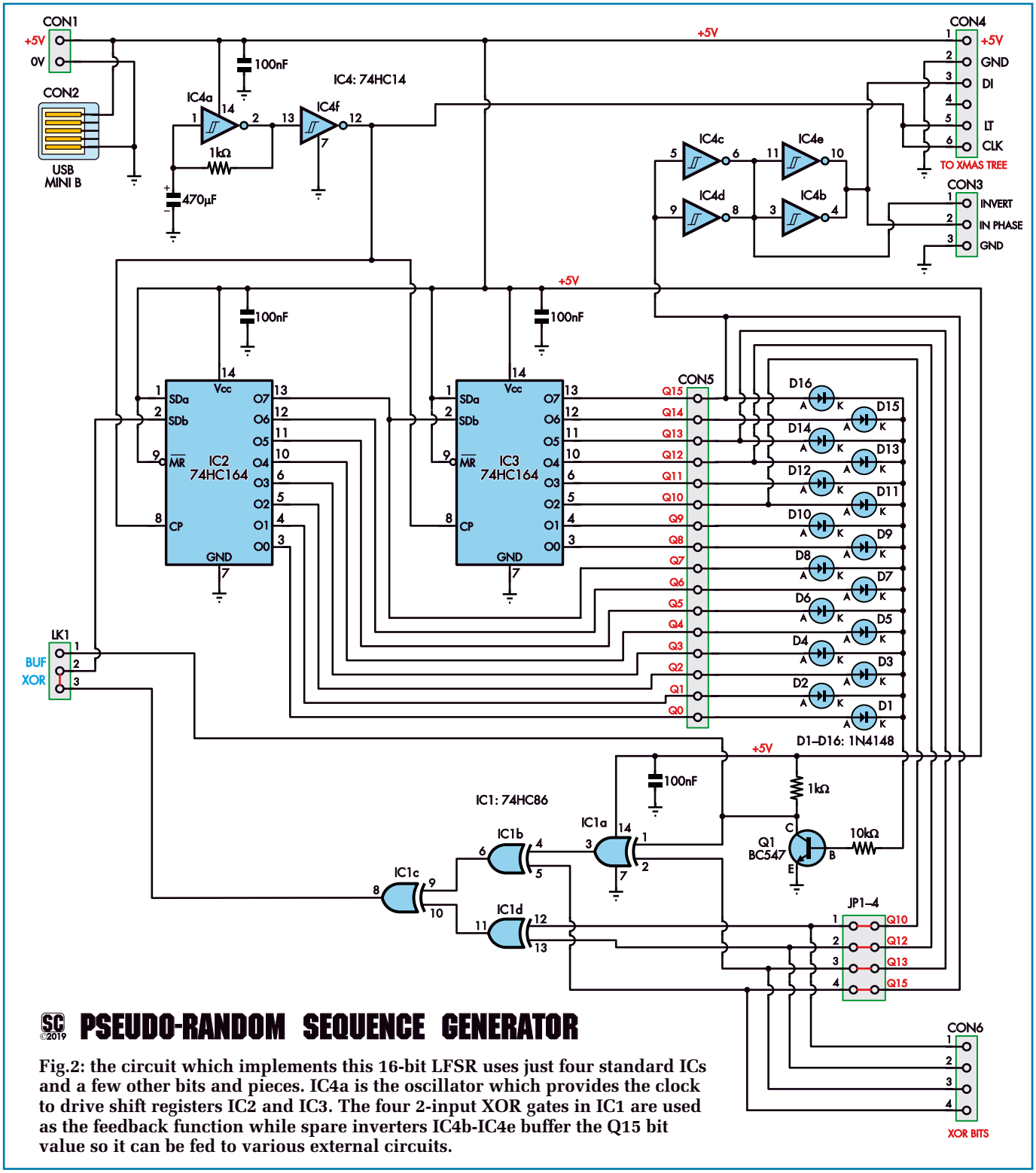
We decided that having four shift register ICs, plus the supporting componentry, would be too large; after all, we want to keep this device simple, so you can easily see how it works. And anyway, the White Noise Generator had a very high clock rate of around 154kHz, which was necessary to produce pleasant-sounding noise over the audio bandwidth of 20Hz-20kHz.

In this example, we want to be able to see the patterns generated, so even if you are updating a large set of LEDs quite rapidly, you don't need a clock rate of more than a couple of kilohertz. So despite the much smaller register size, the repetition period is still quite long.

The way that we are combining the output of the shift register with some of its contents is a basic boolean logic operation called exclusive or, abbreviated to 'XOR'. A two-input XOR has a balanced truth table, with four possible input combinations (00, 01, 10, 11) and the result is equally likely to be a zero or a one (00 => 0, 01 => 1, 10 => 1, 11 => 0).

This is important because operations which do not produce an equal number of zero or one outcomes for a random distribution of input values will rapidly cause the bits in the register to become all zero or all one; not what we want when we are trying to generate a random looking pattern!

By the way, we haven't explained how the random values translate into light patterns, but hopefully you have figured it out: we can feed the 'random' series of zeros and ones into the Christmas Tree and for each bit which is one, the corresponding LED will be on, and for each



PSEUDO-RANDOM SEQUENCE GENERATOR

Fig.2: the circuit which implements this 16-bit LFSR uses just four standard ICs and a few other bits and pieces. IC4a is the oscillator which provides the clock to drive shift registers IC2 and IC3. The four 2-input XOR gates in IC1 are used as the feedback function while spare inverters IC4b-IC4e buffer the Q15 bit value so it can be fed to various external circuits.

bit which is zero, it will be off. If we shift these values in rapidly, the LEDs will appear to twinkle, like stars.

Linear operations in logic

We mentioned earlier that the term "linear" does not mean the same thing in mathematics as it does in electronics. In electronics, it suggests that the circuit is operating in the analog domain; this circuit is decidedly digital.

In boolean logic, 'linear' basically means that the function F satisfies the equation aF(x + y) = aF(x) + aF(y). Our XOR operation satisfies that condition.

To expand on why XOR is a good choice, and why we said earlier that it's good that it has a 'balanced' truth table, consider what would happen if we used the similar AND function instead. A zero at the output of the shift register would always give a zero at the input, and as a result, it wouldn't take long for all the bits to become zero. They would then stay that way forever.

Similarly, if we used an OR function instead, the register would fill with ones in short order. On the other hand, XNOR could be used instead of XOR, as it has a very similar truth table to XOR.

There is one scenario in which the XOR function doesn't work well, and that's when all the inputs all start as zero, as then the output is always zero, so the register will get stuck in this state. Our circuit has extra components to detect this state and override the output in that case.

We have also carefully chosen which bits are XORed together to ensure our sequence does not repeat prematurely.

With a 16-bit linear feedback shift register and well-chosen 'taps', we can cycle through 65535 (2^{16}-1) states before the sequence repeats.

With a 2Hz update rate, that means the sequence will take over nine hours to repeat. The taps we're using are shown in Fig.1. These guarantee the maximum repetition period, as stated above.

See the 2018 White Noise Generator article (link above) for more background on how this type of a pseudo-random number generator works.

Parts list – Pseudo-Random Sequence Generator

1 double-sided PCB coded 16106191, 91.5mm x 63mm
1 2-pin header (CON1)
1 SMD mini type-B USB socket (CON2; optional)
2 3-pin headers (CON3,LK1)
1 6-way female header (CON4)
1 16-way female header (CON5; optional)
1 4-way female header (CON6; optional)
1 2x4-way pin header (JP1-JP4)
5 jumper shunts (for JP1-JP4 & LK1)
4 14-pin DIL IC sockets (for IC1-IC4; optional)

Semiconductors
1 74HC86 quad XOR gate, DIP-14 (IC1)
2 74HC164 8-bit shift register, DIP-14 (IC2, IC3)
1 74HC14 hex Schmitt trigger inverter, DIP-14 (IC4)
16 1N4148 small signal diodes (D1-D16)
1 BC547 NPN transistor (Q1)

Capacitors
1 470µF 10V electrolytic
4 100nF ceramic or MKT

Resistors (all 1/4W 5% or 1%)

	4-band code (5%)	*5-band code (1%)*
1 10kΩ	*brown black orange gold*	*brown black black red brown*
2 1kΩ	*brown black red gold*	*brown black black brown brown*

Circuit description

The circuit is shown in Fig.2. We've kept it as simple as possible, so it's based on just four logic ICs, one transistor, sixteen diodes and just a few resistors and capacitors.

IC2 and IC3 are the two eight-bit shift registers, and they are cascaded to form a single 16-bit shift register. This is done by holding the O7 output of IC2 to the SDb input (pin 2) of IC3, tying the clock input pins (pin 8 of each IC) together and holding the SDa and $\overline{MR}$ pins high. This means that the SDb input determines the input state of the shift register, and the chips are always active.

As a result, the value of a bit fed into pin 2 of IC2 (zero or one) will appear 16 clock pulses later at pin 13 of IC3. Pins 3-7 and 10-13 of both ICs are outputs carrying the values of the individual bits from each shift register.

The common clock pins are driven from pin 12 of IC4f, a Schmitt trigger inverter, which buffers the output of oscillator IC4a. This is another Schmitt trigger inverter with a resistor and capacitor in the feedback loop, causing it to oscillate at around 2Hz. You can change this frequency by varying either the resistor or capacitor values; increase either to slow it down or decrease either to speed it up.

It's important that a Schmitt trigger inverter is used for this oscillator since the built-in hysteresis (ie, the difference in positive-going and negative going input switching voltage thresholds) ensures that it oscillates and also makes the frequency fairly predictable.

XOR gates

IC1 is a 74HC86 quad XOR gate. The four gates are combined to effectively provide a single five-input XOR gate, with these inputs being at pins 1, 2, 5, 12 & 13 and the result is available at pin 8.

Usually, jumpers JP1-JP4 will be inserted, and LK1 will be in the position shown in Fig.2, so four of these inputs are connected to outputs Q10, Q12, Q13 and Q15 of the shift register. This gives us the configuration shown earlier in Fig.1, with one additional XOR input.

This fifth XOR input comes from a 16-input NOR gate, built from diodes D1-D16, NPN transistor Q1 and its two biasing resistors. In practice, what this means is that transistor Q1 is switched on as long as at least one of the Q1-Q16 outputs of the shift register is high (1). In this case, its collector will be low, so the fifth XOR input at pin 1 of IC1a will also be low.

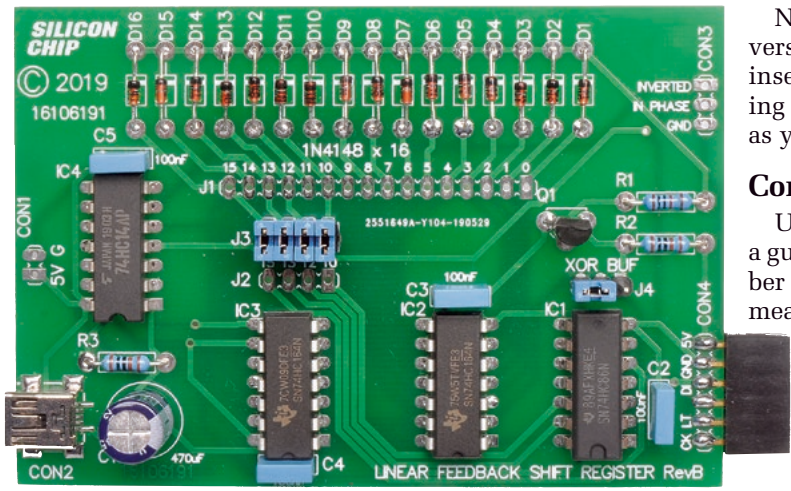
However, if the shift register contains all zeros, none of diodes D1-D16 will be forward biased and so transistor Q1 switches off, allowing the 1kΩ resistor to pull its collector high, to +5V. This then causes the output of our five-way XOR gate to be one, not zero, ensuring that the shift register cannot stay in the all zeros state for more than one cycle, as a one will be fed into its input in this case.

The output of the XOR gate is normally fed to the shift register input, pin 2 of IC2, via LK1. If LK1 is instead placed in its alternative position, the output of the shift register is merely fed back into the input. Because Q1 prevents it from being all zeros all the time, this has the effect of one output being high, which then moves from one end of the shift register to the other, before repeating.

When this unit is connected to the LED Christmas Tree, that causes it to generate a 'chaser' effect as one lit LED moves through the tree every seventeen clock pulses.

Driving external circuitry

The four spare inverters in IC4 (ie, those not used for the



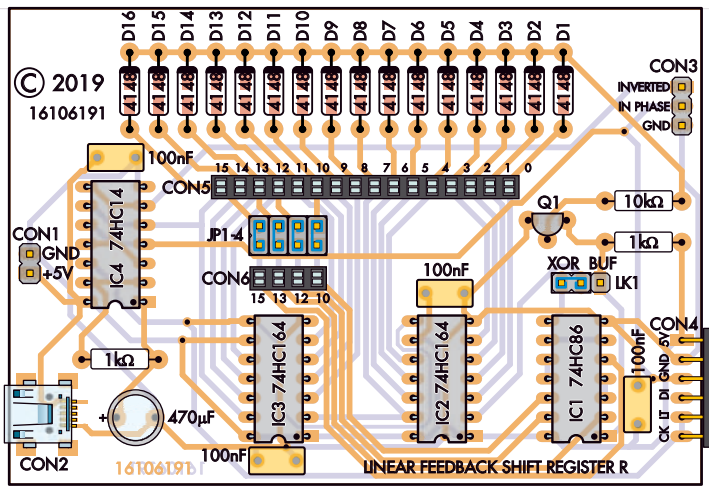


Fig.3: like the circuit, the PCB layout is quite simple. The main thing to watch while building it is the orientations of IC1-IC4 and D1-D16. Various headers and jumpers are provided so you can experiment with and probe the circuit to see what happens if you change it slightly. A header socket is provided to allow the board to directly drive a Stackable LED Christmas Tree, (as seen on page 85) with as few as 10 LEDs or as many as several hundred.

oscillator) are paired up to buffer the output of the shift register. The O7 output from pin 13 of IC3 is fed to input pins 5 and 9 of inverters IC4c and IC4d, and their outputs are also paralleled and connected to pin 1 of CON3, to provide a bit more drive current for any external circuitry connected there.

That signal is then similarly re-inverted by IC4b and IC4e, to provide an in-phase buffered output at pin 2 of CON3. This gives us complementary signals at pins 1 & 2 of CON3, which could provide a 10V peak-to-peak signal for driving a piezo (for example).

The in-phase output is also fed to the DI pin of CON4, which has a pinout designed to match the Stackable LED Christmas Tree, so it can be used to drive a tree directly. The buffered clock signal is taken to the CLK and LT pins on CON4, so that each bit of pseudo-random data fed to the tree is synchronously shifted all through the tree.

The power supply for this circuit is elementary: a 5V DC externally regulated supply is fed in via either USB socket CON2 or pin header CON1. Bulk bypassing is not required; one 100nF capacitor per IC is sufficient.

Note that the USB socket provides a measure of reverse polarity protection, as the USB plug can only be inserted one way, while there is no protection when using pin header CON1. So be careful when wiring CON1 as you'll fry the board if you reverse it.

Construction

Use the PCB overlay diagram, Fig.3, and the photos as a guide during construction. The Pseudo-random Number Generator is built on a PCB coded 16106191 which measures 91.5 x 63mm.

If you are fitting CON2, the optional surface-mounted mini-USB socket for power, do this first. Apply some solder flux to the pads on the PCB and locate the socket with its pins into the holes on the PCB. Solder one of the side mechanical tabs in place and ensure that the pins line up with their pads before proceeding.

Load the iron with a small amount of solder and touch the iron to the pads. The solder should flow onto the pad and the pins. Only the two end pins for power are needed. Check that there are no bridges to adjacent pins, and if there are, carefully remove with solder braid or wick. Once you are happy that the power pins are soldered correctly, solder the remaining mechanical pins.

Now move onto the resistors and diodes. Make sure that the diodes are all orientated correctly, ie, with their cathodes stripes towards the top of the board.

Then solder the ICs in place. You can use sockets if you wish. These must also be orientated correctly, with the pin 1 dot/notch in each case towards the bottom of the board. Don't get the chips mixed up since there are three different types, but they all have the same number of pins (14).

You may need to carefully bend the legs on the ICs so that they are straight and vertical before they will fit. Solder two diagonally opposite pins on each IC, then check the orientation and that the IC is flat against the PCB before soldering the remaining pins.

The four small 100nF capacitors are not polarised. Fit them now. Follow with the sole transistor, Q2, with its flat face orientated as shown. You may need to carefully bend its legs to fit the PCB.

Fit the pin headers next, including CON1, CON3, LK1 and JP1-JP4. Follow with header socket CON4, mounted at right-angles, so it can plug into the male header on an LED Christmas Tree board. This can be done by surface-mounting it to the pads on top of the PCB rather than soldering it into the through-holes. If you want your tree to project up from this board, CON4 can be fitted vertically instead.

Now fit optional headers CON5 and CON6, if desired. These are provided to allow you to experiment by feeding different combinations of the sixteen shift register outputs into the XOR gate inputs. We've recommended using female headers for these so that so you can make connections using male-male jumper wires, but other combinations are possible. Finally, fit the electrolytic capacitor, ensuring its longer positive lead goes into the hole marked with the "+" sign, then plug jumper shunts into JP1-JP4 and LK1 as shown in Figs.2 and 3.

Testing

If you have a Christmas Tree PCB, plug it into CON4, en-

suring the pin functions line up correctly (ie, it is not reversed) and apply regulated 5V DC power through either the USB socket (CON2) or pin header (CON1). You should see the LEDs on the tree start to flash, although depending on the initial state of the shift registers, it may take 10-15 seconds before you see anything.

Hint: if you aren't using CON2, you can easily get the 5V DC required to feed to CON1 from the pins of a USB/serial adaptor plugged into a USB port.

If you don't have a Christmas Tree PCB, you can connect a simple LED in series with a 1kΩ series resistor across pins 2 and 3 of CON3, or even connect a piezo speaker (eg, Jaycar AB3440) to these pins (in this case, a faster clock rate is advsed.

Alternatively, you can connect these devices to CON3, between either pin 1 or pin 2, and pin 3 (GND).

Further experimentation

Finally, if you want to see what makes the LFSR' tick', JP1-JP4, CON5 and CON6 can be used to change the 'taps', ie, which shift register bits are combined to define the shift register's input state.

To do this, remove the shorting blocks from JP1-JP4 and use patch leads to connect the four outputs that you want to feed back from the terminals of CON5 to the pins of CON6 (the order doesn't matter).

If you want to use fewer than four inputs to the XOR gate, wire the unused pins of CON6 to either GND or +5V.

The taps we have used with JP1-JP4 inserted provide a so-called maximal length sequence (65,535 steps for a 16-bit shift register), but there are other combinations of taps which also create a maximal length, as well as a number that are much shorter.

Also note that if Q15 (ie, the last bit of the shift register) is not fed into the XOR gate, then that will necessarily result in a shorter sequence.

The article at siliconchip.com.au/link/aasj has more information on the mathematical theory of linear feedback shift registers, and also how they are used in fields such as cryptography and digital communications.

As mentioned earlier, if used to drive the LED Christmas Tree, you can place LK1 in its alternative position to switch the circuit into chaser mode.

If you decide to adjust the operating frequency as described above, by varying the value of either the 470µF capacitor or nearby 1kΩ resistor, keep in mind that this resistor value can't go much below 470Ω due to the limited output current of IC4a.

So to increase the frequency, you're better off reducing the capacitor value (lower value capacitors are usually cheaper, too!).

You can increase the resistor value, so if you want to make the frequency variable, you could use connect a 10kΩ potentiometer (or similar) in series with a 470Ω resistor between pins 1 and 2 of IC4a, then reduce the timing capacitor value to 4.7µF to give an adjustable frequency of around 2-40Hz.

If you reduce the timing capacitor to 33nF, that will give a clock rate of about 20kHz, and you will then get a signal that's suitable for basic audio use, as a white noise source. But note that at this rate, it's hardly even a pseudo-random number generator: the sequence will repeat every few seconds, and that will be quite apparent. SC

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

PICAXE "Knight Rider" LED chaser display

Over the years many Knight Rider displays have been published, all inspired by the original design used in the 1982-1986 TV series.

The Knight Rider car featured a row of lamps, recessed into the grille at the front of the car, switched on sequentially to produce a back-and-forth chaser display. This circuit drives LEDs similarly and can be used for model cars, robot projects etc.

It's based on a PICAXE20M2 microcontroller (IC1) with the chaser patterns and speed controlled by the software. You can select six chaser patterns by rotating VR1 while VR2 varies the speed. Fitting a jumper on JP1 will override VR1 and cause the unit to continually cycle the first three chaser patterns, while a link on JP2 will force it to cycle the remaining three chaser patterns.

LEDs1-12 should be arranged in a single row. The six patterns are:

1) 1 x 12 way Knight Rider display
2) 2 x 6 way Knight Rider display
3) 3 x 4 way Knight Rider display

Patterns 4-6 are the same as patterns 1-3 except that two LEDs are lit at any given time, instead of just one.

The LEDs are driven by 12 output pins from microcontroller IC1, via 150Ω current-limiting resistors. This value suits a wide range of LEDs. They may be any colour; the brighter, the better. For the prototype, I used high-brightness white LEDs.

Mode and speed potentiometers VR1 and VR2 are monitored by analog inputs C7 (pin 3) and B0 (pin 18) of IC1. It measures the voltage level on the wipers of each pot. The state of jumpers JP1 and JP2 are monitored by digital inputs C6 (pin 4) and B1 (pin 17). These pins are held high by pull-ups inside IC1, but are pulled low if a jumper is fitted.

Power comes from a 6V battery pack (eg, four AA cells), which is switched by power switch S1. Diode D1 provides reverse polarity protection and also drops the battery voltage to just over 5V, below the maximum 5.5V allowable for microcontroller IC1.

100µF and 100nF bypass capacitors are used to stabilise its supply. ICSP socket CON1 connects to the serial input (pin 2) and serial output (pin 19) on IC1, so you can load programs onto it using a PICAXE programming cable.

If you mount the display inside another device, it may be able to draw power from that device's battery. If its battery voltage is too high (say, 12V), you could use a 7805 regulator or similar to derive a 5V supply.

The LEDs could be replaced with transistors to drive lamps or other high current loads. Better still, you could use two ULN2003N Darlington transistor driver ICs for this purpose.

My prototype was built on two IC prototyping boards, with the microcontroller on one board and the 12 LEDs on the other. These boards were mounted in a Jiffy box, along with the battery and power switch.

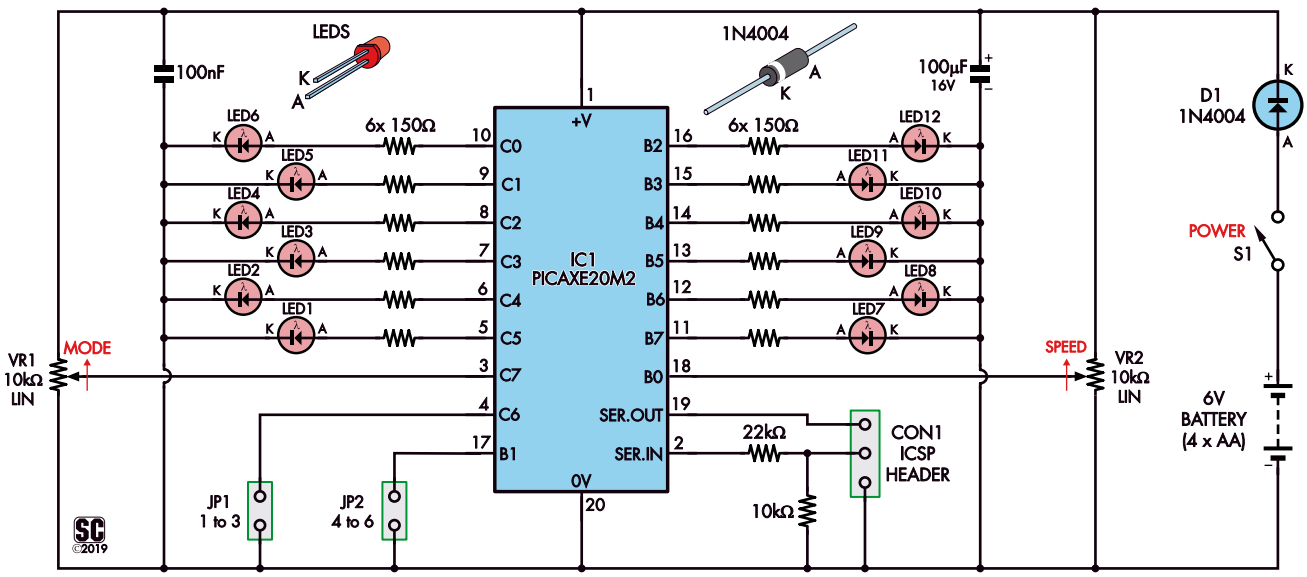
You could dispense with the case and mount the boards directly into a model car, a robot project or any other device that takes your fancy.

VR1 and VR2 can be either trimpots or standard potentiometers, depending on your application.

The PICAXE website explains how to use your computer to program the PICAXE20M2. You will need an AXE027 USB cable (www.picaxestore.com/axe027 or siliconchip.com.au/link/aari) and a copy of the free "program editor software" and "USB driver software" from the PICAXE website.

Download my PICAXE Basic program ("knight_rider_20m2.bas") from the Silicon Chip website, and then load this program using the USB cable connected to the in circuit serial programming (ICSP) header, using the program editor software.

Ian Robertson,
Engadine, NSW. ($65)



Voice modulator for sound effects

I built this circuit to simulate voices from science fiction shows such as Dr Who's Daleks and Cybermen. You speak into a microphone, and the unit produces a modified output, making you sound like one of those characters, by modulating the sound with an oscillator waveform.

The optimum oscillator for a Dalek voice is a 35-45Hz square wave. For the Cyberman voice, it's an 80-120Hz sinewave.

If you feed in recorded music or connect it to a guitar pickup rather than a microphone, it will produce a variety of interesting and weird effects, especially when modulating with very low frequency or with a high frequency harmonic related to the input signal. So it can be used for music and instrument effects, too.

Audio is fed in either via CON1 or CON2, depending on the source. You also need to feed in an external oscillator signal to CON3, which may come from a function generator or similar. The audio is AC-coupled to level adjustment potentiometer VR1, then AC-coupled again to the base of NPN transistor Q1.

This is biased to operate as a common-emitter amplifier. The signal from its collector is then fed to the base of NPN transistor Q2, which operates as an emitter-follower buffer, to drive the primary of isolating transformer T1, via a 10µF coupling capacitor.

T1 acts as a mixer, allowing the oscillator signal (level adjusted using VR2) to modulate the audio signal. The resulting balanced signal is then optionally fed to one of two diode bridges, as selected using the four-pole, three-position rotary switch S2, or straight to the output transformer.

In the position shown, the signal passes through a bridge of four germanium diodes before being applied to the centre-tapped primary of transformer T2.

If switched to the next position, the signal instead passes through a bridge of four silicon diodes. And in the third position, the signal passes straight through to T2. This gives you three further options to modify the type of effect generated.

T2 converts the sound back to a single-ended audio signal and provides some filtering, with the 1nF capacitor across its secondary, to cut out very high harmonics which would make the resulting sound too harsh. VR3 provides an output level adjustment, and the resulting signal is fed to output socket CON4.

While not overly critical, it's best if the four diodes in each bridge are well matched to each other. This can be done by measuring their forward resistance on an analog multimeter set to 1X scale – or a DMM with a diode test and voltage measurement function – and selecting the four which are most similar from a larger set.

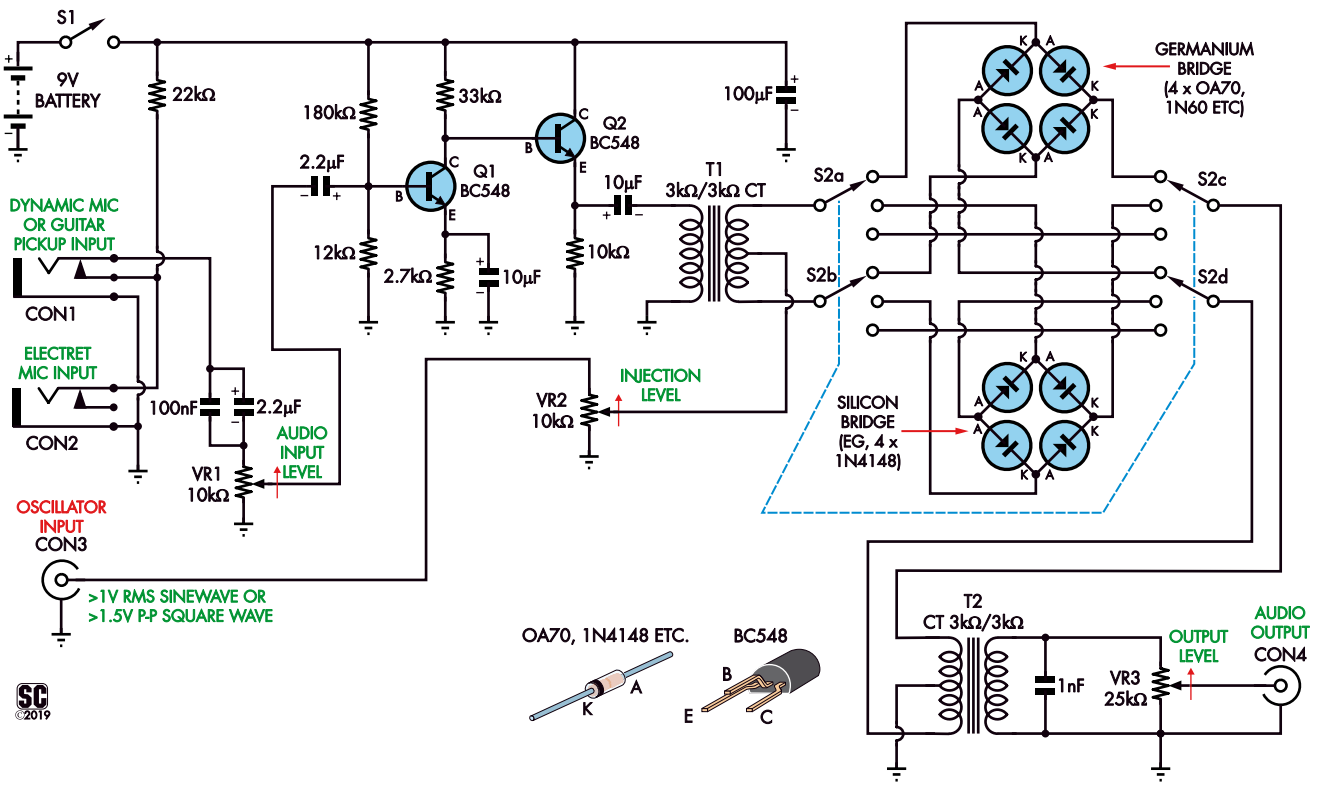
To use the unit, initially set switch S2 to "bypass" (ie, the third position) and adjust the input signal up to the point of no clipping/distortion at the output. You can then switch S2 to use the germanium bridge (a softer modulation result) or the silicon bridge (a much harsher result) and adjust the oscillator frequency for the desired effect.

The oscillator signal needs to be at least 1V RMS (for a sinewave) or 1.5V peak-to-peak (for a square wave) to enable the diodes to conduct.

Depending on the oscillator injection level, modulation can vary from slight to a harsh chopping of the signal.

Sinewave modulation gives a smoother output, especially with musical sources. The two diode bridges can be soldered directly to the selector switch terminals.

Warwick Talbot
Toowoomba, Qld ($80).



Arduino LoRa chat terminal with QWERTY keyboard

I live near Bandhavgarh tiger reserve, a 1150km^2 area with a core jungle area of 820km^2 where only rangers are allowed. In this area, mobile phone coverage is abysmal.

One day, I was chatting with a ranger and asked him how he communicates when in the jungle. He showed me a huge microwave tower which runs on solar and battery power, and he complained that it hardly works when it's needed. It's 10 years old and a power guzzler – after one or two sentences, the power goes out.

So I came up with the idea of using LoRa transceivers to provide a chat terminal which can be used in this remote area. I figured that would be more reliable than voice communication.

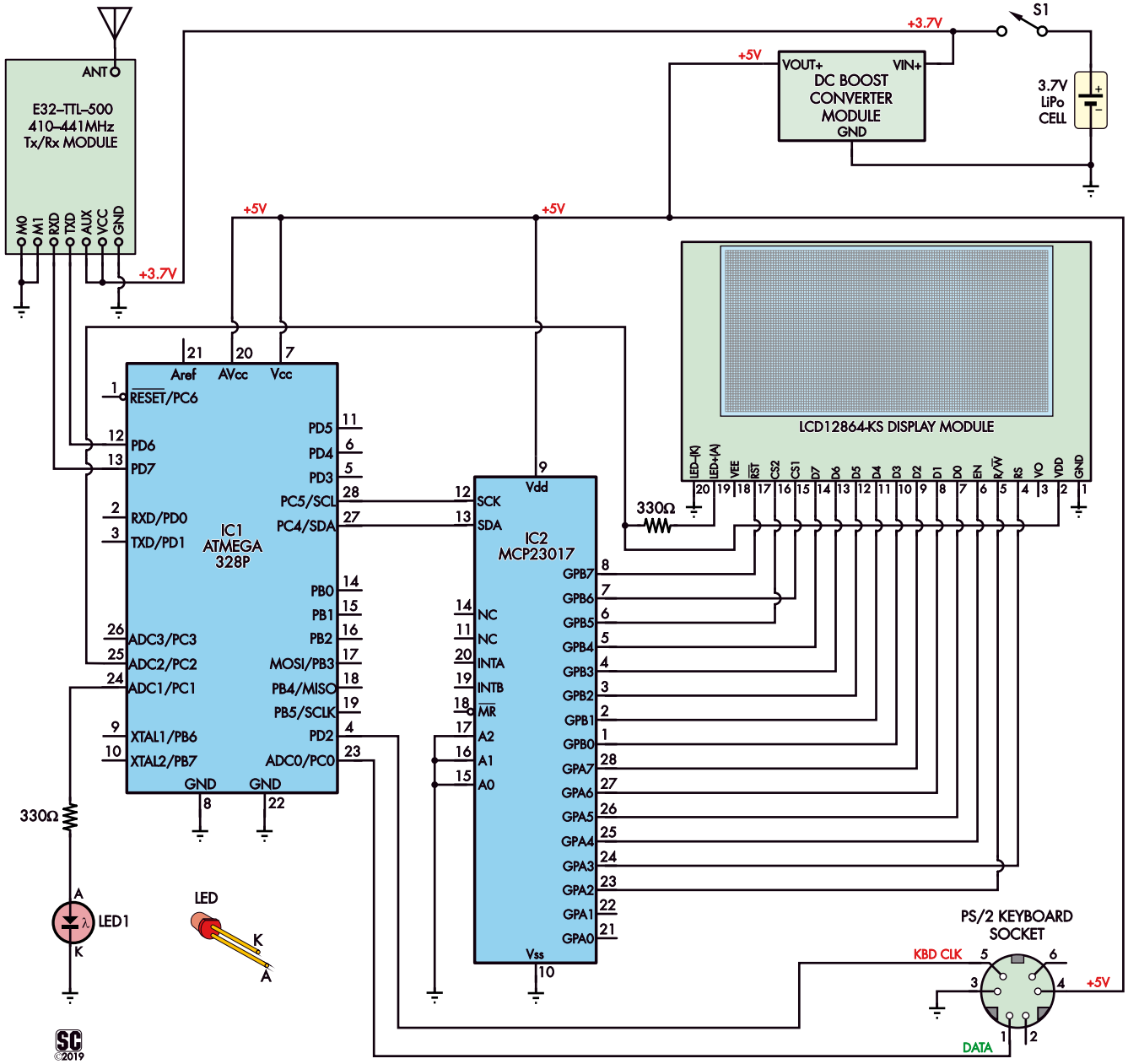
It uses LoRa modules operating at 868MHz with 0.5-1W transmit power and a small whip antenna, operating at 1200-9600 baud. Text is shown on a 128x64 pixel monochrome LCD screen and entered using an old PS/2 keyboard, and the whole thing is managed by a low-power ATmega328 (Arduino) chip running at 8MHz.

In India, 865-867MHz is a free band in which there are 8 channels spaced 250kHz apart. But this is not legal for use in many other countries, including Australia and New Zealand.

Luckily, LoRa modules are available which operate on several different bands, including the 434MHz industrial, scientific and medical (ISM) band, which can be used in most countries as long as the output power is kept within specified limits. In Australia and New Zealand, this limit is 25mW.

You can use the RFSet software to set your LoRa module radio parameters to ensure that they comply with local regulations. In the same RFSet software you can set a four-byte ID code so that your modules can only communicate with other modules with the same ID code.

The system will run for 10-12 hours from a small 3.7V mobile phone battery. This can easily be charged by a small solar cell in a few hours.



One of the challenges of this design is that the LCD screen and PS/2 keyboard require a 5V supply while the battery voltage varies between 3.3V and 4.2V, so a boost regulator is needed. The MT3608 2A step-up module (Silicon Chip Online Shop Cat SC4437) is suitable and costs a measly $2.

In operation, the LCD screen is divided into two windows; four lines of text at the top are used to see what you are sending while four lines at the bottom show the received text. A line separates the two areas of the screen. A very simple text editor is used in the top window, allowing the easy creation of chat messages.

This responds to the following keys on the keyboard: all alphanumeric keys and the space bar (for entering text), left and right arrows (for moving the cursor), backspace and DEL (for editing text) and ESC (to clear the screen). To send a message, you type your text and then press the "#" (hash) key. When a message is received, LED1 lights up.

Turning to the circuit, the LoRa module is powered directly from the 3.7V LiPo cell and is controlled by the Arduino over a bidirectional serial port on its PD6 and PD7 I/O pins. The micro doesn't have enough pins to drive the screen directly, so an MCP23017 I/O expander connects the two. This is controlled over an I^2C bus and it drives all the screen's I/O pins.

Pins 15-17 of IC2 set its I^2C address, and these are all tied to 0V, setting its address to 0x20. This is the address that the supplied software for IC1 sends its command to.

The PS/2 keyboard's data and clock pins go to the PC0 and PD2 I/O pins on IC1 respectively.

To save power, the LCD screen's logic (V_{DD}) and backlight (V_A) supply come from I/O pin PC2 of IC1. This pin is driven high to power the LCD. It can supply just enough current to run the screen, with the backlight current limited by a 330Ω resistor. This way, the screen can be shut down when it is not being used, resulting in significant power savings.

The screen is shut down when the ESC key on the keyboard is pressed. But when there is an incoming message or another key on the keyboard is pressed, the screen is powered back up.

Testing has shown that a small 5dBi antenna on a mast is sufficient to allow the device to communicate between a ranger in the jungle and the home base. With maximum power (30dBm) and 1200 baud operation, we've found the range to be around 10-40km depending on location.

All the modules needed to build this Chat Terminal are available from websites like eBay and AliExpress, while the Arduino software can be downloaded from the Silicon Chip website.

As it's running on a standalone ATmega328 chip without a crystal oscillator, you will need to install the "Breadboard" Arduino bootloader first, as explained at: www.arduino.cc/en/Tutorial/ArduinoToBreadboard

Bera Somnath,
Vindhyanagar, India. ($90)

Phantom-powered microphone over telephone cables

I designed this circuit to provide sound for my CCTV video surveillance system, as it will work over telephone wire or Cat5 cables.

This avoids the need for long runs of coaxial cable or an always-on wireless link in an overcrowded radio spectrum.

It uses an LM386 audio amplifier to drive two back-to-back audio transformers as part of a basic unbalanced phantom power circuit.

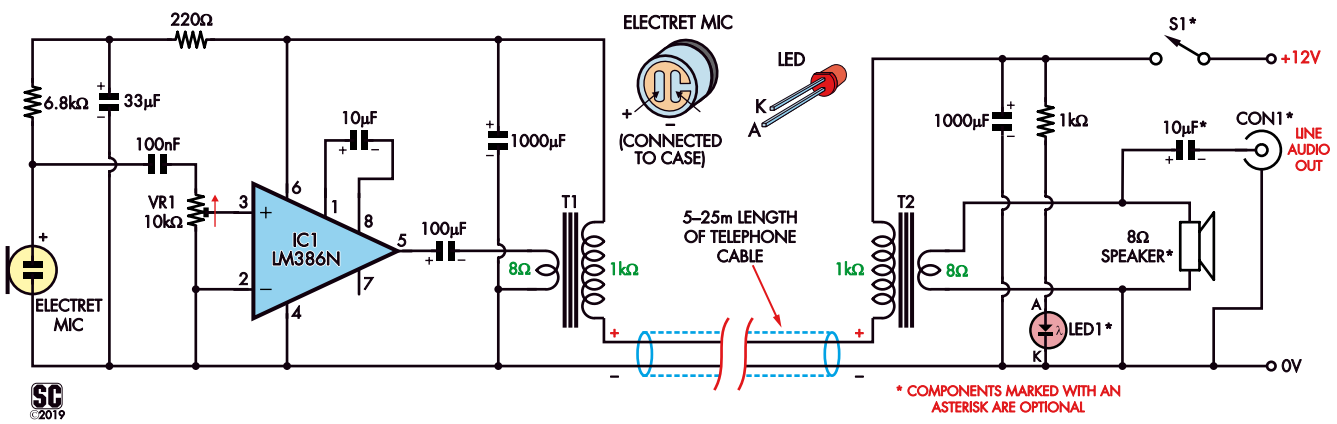
It's powered from a 12V DC supply, with the supply voltage to the LM386 IC varying over a range of about 4-6V. A small 10kΩ potentiometer (VR1) is used to set the sound level.

The electret condenser microphone is very sensitive, so continuous loud sounds will cause the amplifier to drop out, as its supply voltage falls too low if its current draw becomes excessive. For this reason, this circuit is not really suitable for music or any continuous high-level sounds, but it's fine as a baby monitor or CCTV microphone.

The noise level is kept low by amplifying the microphone signal before feeding it over the long cable. Also, the power supply for the electret is filtered by a 220Ω resistor and 33µF capacitor to remove any high-frequency noise that may have been picked up in the cable.

You can fit a small speaker at the receiving end, or couple the signal to a line out socket, or both. The LED and series resistor are optional, to provide a convenient indication that the circuit is powered. You could also fit a power indicator LED across the supply at the remote end if desired.

John Crowhurst,
Mitchell Park, SA. ($75)



AM radio distribution amplifier

While unusual, it is possible to improve AM reception indoors (especially in a large building with a metal roof) by feeding the output of an outdoor AM antenna to a distribution amplifier like this.

It buffers the signal picked up by the external antenna and feeds it either directly to AM radios with external antenna sockets (fairly uncommon), or to indoor antennas, to be radiated and then picked up by the internal antennas of radios within the structure.

You could use AM loop antennas (available on eBay etc) or merely long wires for both the outdoor and indoor antennas.

The signal from the external antenna is clamped to ±0.6V using a 100Ω series resistor and two small signal diodes (D1 & D2) connected in inverse parallel. This protects the circuit from EMI and inductive coupling due to distance lightning – it won't do much in the case of a direct strike, so the indoor antennas should be mounted away from people.

The signal is fed to the base of four low-noise NPN transistors (Q1-Q4; BC550C) via 10nF coupling capacitors. You can adjust the number of buffer stages to suit your application. Each one is identical.

The base of each transistor is DC biased to around 1.5V by a pair of 1MΩ resistors. This is less than the 2.5V than you might expect from a resistive divider across the 5V supply rail; the difference is due to the base current which bypasses the bottom resistor in the divider. The transistor emitters sit at around 1mA, ie, there is around 1V across the 1kΩ emitter resistors.

The AC signal from the antenna modulates the transistor base voltages, and since the transistors are configured as emitter-followers, a signal with almost the same amplitude (just a little bit lower) appears at the emitters.

The point of these transistors is not to provide gain, but to prevent the external antenna from being loaded by the low impedances of the indoor antennas, which would otherwise result in minimal coupling between the two.

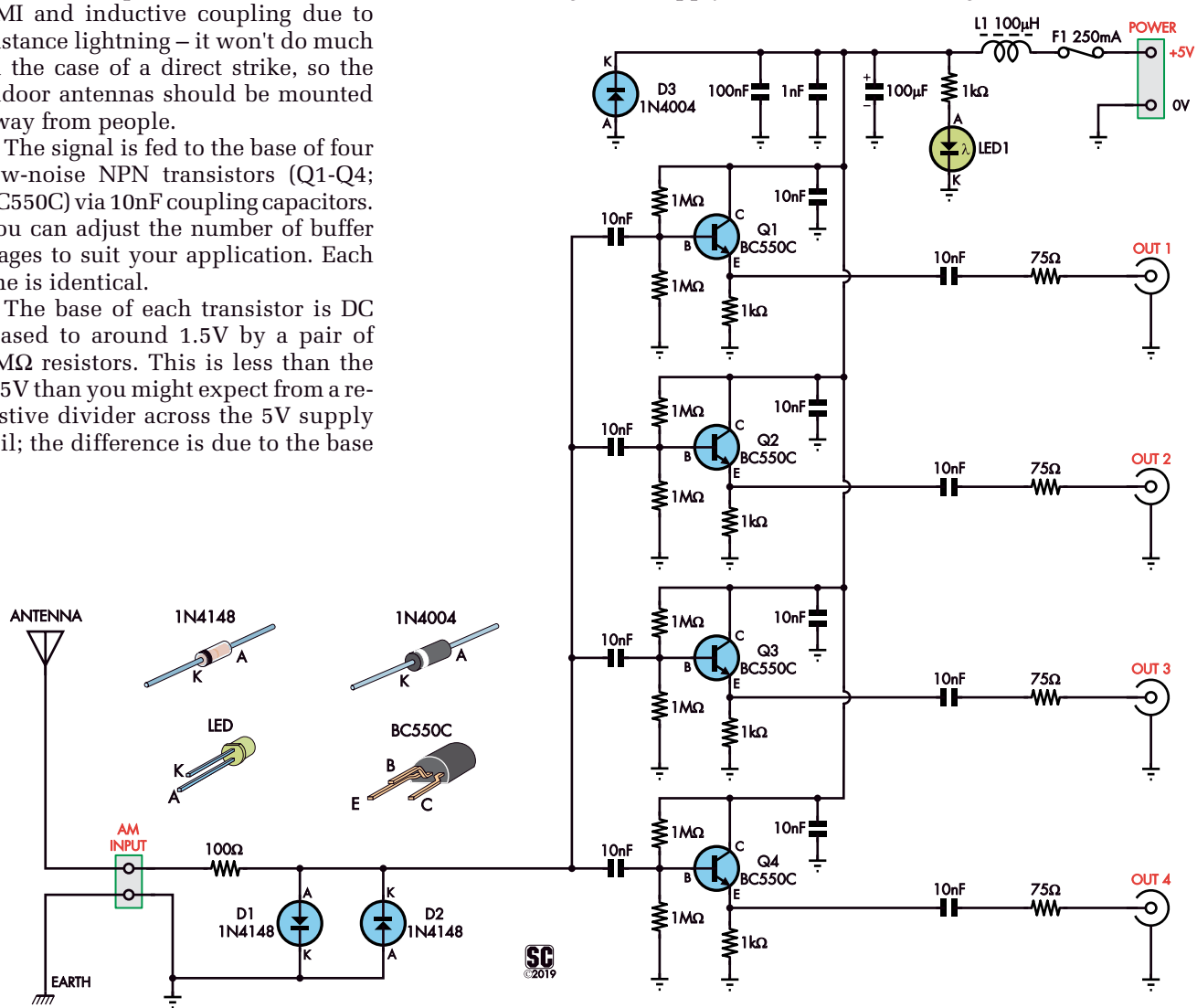
The circuit will pass signals up to around 3MHz, limited by the ~1mA transistor collector current.

The circuit is powered from an external 5V DC regulated supply, which is filtered by a 100µH series inductor and several capacitors to ground, with different values so that they are more effective at different frequency ranges. This supply powers LED1 to indicate that the circuit is operating. If the supply is accidentally connected in reverse, diode D3 will conduct and blow fuse F1.

One advantage of using indoor antennas to re-radiate the signals is that you will not have an electrical pathway between the antenna on the roof and indoor sockets/radios, which could otherwise conduct lightning strikes.

If you are using a circuit like this to connect directly to antenna input sockets, it is a good idea to unplug the radios and stay away from the wiring during thunderstorms.

Petre Petrov,
Sofia, Bulgaria. ($60)



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VINTAGE RADIO

By Dennis Jackson

The 1924 RCA AR-812 superhet radio receiver

This was the world's first commercially available superheterodyne radio and a "portable" set to boot – the RCA AG-814 external aerial loop antenna and model 100 loudspeaker puts its total weight close to 30kg! This set uses just six UV199 triodes, with most components tucked away in the "catacomb", a metal container sealed with a wax-like substance (in this case rosin). The intention was to prevent competitors learning about how the radio was designed.

We are fortunate to be living in a time of rapid technological progress. Yet few of us are aware of the great minds whose work long ago underpins many important aspects of that modern technology.

Much of their hard work is now taken for granted, as if the facts and techniques that they worked so hard to acquire have always been obvious.

By around 1900, Guglielmo Marconi had put together the bits and pieces gained by the discoveries of the great researchers before him to become the "Father of Radio Spark Telephony".

But Major Edwin Armstrong, formerly of the US Signal Corps, could be referred to as the father of modern radio, having played the major part in the development of the superheterodyne radio receiver and being the inventor of the regenerative detector. He also developed the Armstrong oscillator which helped to make audio modulation possible.

He came up with and eventually put into practice the concept of frequency modulation which has now become the norm for both radio and television transmissions.

A brief history of the superhet

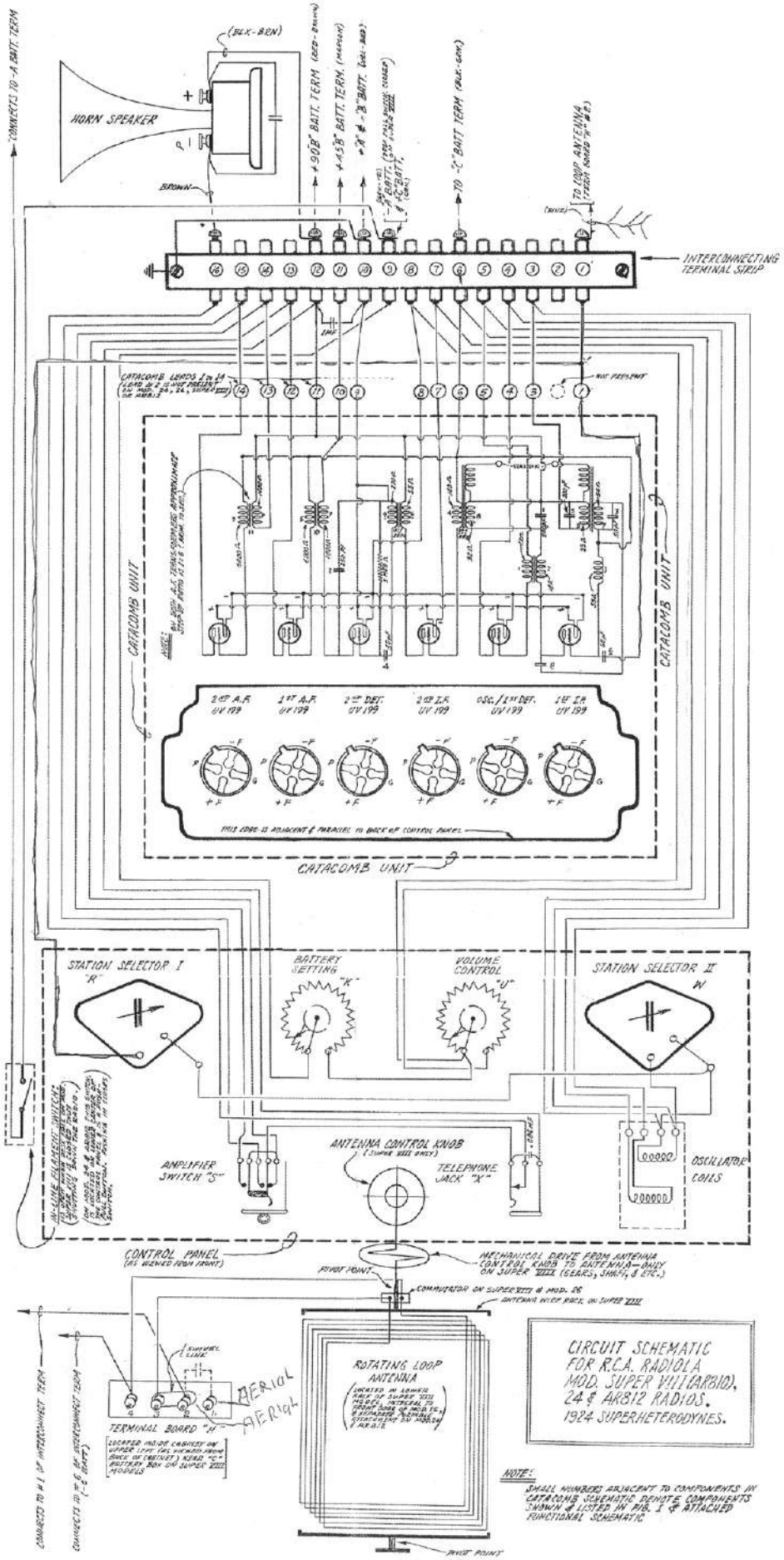
History records that Armstrong was not the first to come up with the idea of the superhet radio. Canadian engineer R. A. Fessenden had made observations concerning beat notes in the transmission of radio signals using Morse code around 1900.

Radio technology developed slowly until the first world war of 1914-18 resulted in an urgent need for radio receivers superior to the tuned radio frequency (TRF) sets then in use for communications. There was also a need to develop direction-finding equipment to detect enemy ships at sea.

Lucien Levy of the French signal corps obtained a patent for a superheterodyne receiver in 1917. Americans entered the conflict in Europe in April 1917 and sent over an expeditionary force.

Major Armstrong was attached to this and he quickly became aware of the poor performance of the sets of the time. He set about investigating the lack of sensitivity and selectivity.

Armstrong believed the problems could be overcome by mixing the



Recreation of the wiring diagram for the AR-812 radio.

incoming signal with a locally produced signal to produce a beat note of a fixed frequency, which could be further filtered by fixed tuned circuits, avoiding the necessity to use variable tuning for each stage of RF amplification as in the TRF receiver.

Armstrong then built the first practical Superhet radio, an eight-valve set which performed better than any others of the day. This was around the time when the armistice was signed, and so the need for radio sets became less urgent.

He applied for a patent covering the Superheterodyne radio on 30 December 1918 and was undoubtedly the first to take out a patent on the Superhet in the USA.

The first consumer Superhet set, the RCA AR-812, came on to the US market in March 1924. These were sold by the Radio Corporation of America, better known as RCA. They were built by the Victor Talking Machine Company. RCA did not manufacture wireless sets until the beginning of the 1930s.

Edwin Armstrong and Harry Houck, who is usually credited with the development of the second harmonic mixer, were the primary engineers for the AR-812.

These sets sold for US $269.00 without batteries, speaker or antenna; a considerable sum of money by today's standards. A Ford Model T motor car could have been purchased for a similar sum at that time.

It is interesting to note some sources claim about 80,000 units were sold. It appears that few of these sets made it to Australia.

Getting hold of an AR-812

Despite this, I noticed one of these sets for sale on eBay about four years ago. It was being offered by an antique shop in Queensland. All of the UV199 valves were missing and I noted that the chassis layout was very unusual, which I found both puzzling and interesting. I was aware of the RCA AR-812 at the time but knew little of its history or development.

Since it was the first true Superhet set, I became convinced that this set would be a very worthwhile addition to my collection of mainly 1920s radios.

The AR-812 duly arrived at my home in Hobart and I must confess to sneaking the box into the workshop through the back gate to avoid any awkward questions about what I had purchased, how much I spent etc. No time was lost getting it all laid out upon the workbench.

The long, narrow table-top cabinet with its carry handle was in good nick. A dose of paint stripper would remove the several layers of very dark varnish applied sometime in the distant past and a careful sanding followed by a couple of coats of spray lacquer would restore its appearance to its previous glory.

A large central front panel hinged down on two locating pins to reveal the works. Central to the interior of the hinged panel and screwed to it was the mysterious metal box known as the "labyrinth".

Two variable tuning condensers were fitted, one on each side of the box. The one on the left was used to manually tune the inbuilt frame aerial and the other on the right to separately tune the local oscillator.

Two pairs of oscillator coils were mounted immediately under the oscillator condenser.

Beginning the restoration

As mentioned earlier, all UV199 valves had been previously removed. I had made a bad mistake by being a bit overeager and had ordered, after a good deal of searching on the internet, a set of UX199 valves of the period via eBay from the USA.

Upon finally receiving these, I discovered I had ordered the wrong type. I really needed the earlier type, the UV199. They are the same valve but the UX199 has a narrower base with shorter pins and a different pinout.

After a further search through the internet, my luck changed and I was able to eventually purchase the six required (and rare) UV199 valves in two lots, four being boxed new old stock.

The mysterious catacomb box proved to be not so mysterious, due to its seals being broken. Its encapsulation, which resembled (and strongly smelled of) pine rosin had partly melted and oozed out to expose its secret contents.

My understanding is that the electronic contents of this catacomb were sealed and encapsulated to protect RCA's then-innovative Superhet circuit from prying eyes and to ensure any servicing required within was done by their staff.

A numbered terminal strip ran along the back and a list of various test points between the strip and the valve sockets was published in the owners' handbook, allowing ohmic readings to be taken along this strip to determine if all was well within. There are also wires connecting terminals on that strip to various valve pins.

There was most likely an exchange system available to servicemen when required. My nerve failed me when I considered the consequences of melting away the rosin, so I began picking away at it with a sharp piece of wire. This worked as the rosin was brittle and came away in small pieces.

Both step-up audio coupling transformers were missing from the set, but the set came with two transformers which appeared to be a good fit, despite appearing to be of much more recent construction. After this set became operable, I experimented with various other transformers, but the two which came with the set gave the best results.

This surprised me because they have a very low DC resistance, the primary being just 300Ω and the secondary, 800Ω. The original transformers that would have come in the set had coils with 1000Ω and 6000Ω DC resistance respectively.

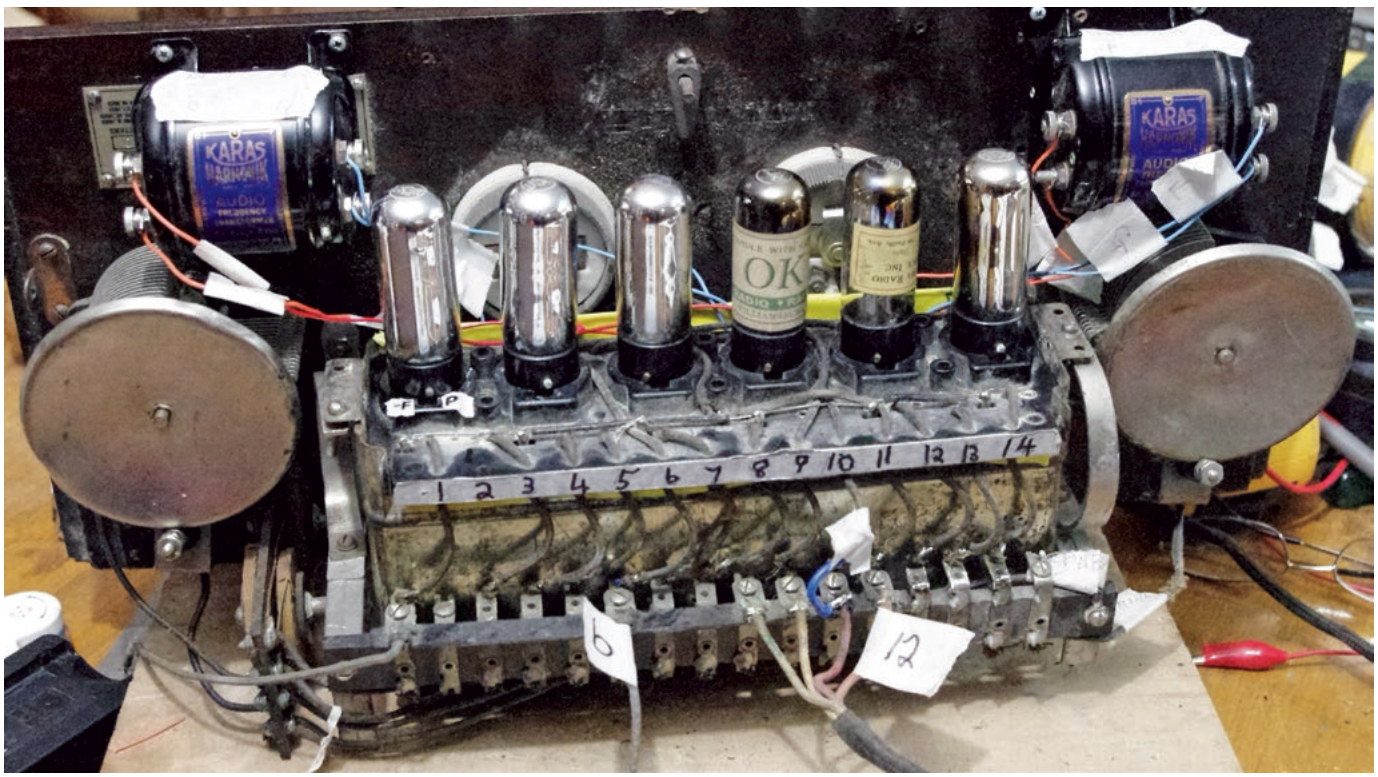
Upon further investigation, it became apparent that the AR-812 front-end circuit was very unconventional (perhaps not surprising, given that superhet conventions hadn't been established yet when it was designed!). Initially lacking a circuit diagram, I began drawing one out on a large piece of paper using coloured pencils.

The mystery deepened and I made only modest headway until I purchased a CD from the USA with a scanned copy of the original operators' manual and a well-drawn circuit diagram made by another enthusiast, who was apparently also an excellent draughtsman.

RCA did not readily give out information regarding the secrets of their catacomb, but there isn't much to go wrong inside it, except for open circuit conductors. My resistance check revealed one open-circuit coil which I removed from the laminated plate and rewound using litz wire salvaged from a disused IF transformer, taking care to count the turns accurately.

There were a few loose wire ends visible, apparently caused by the volatile elements in the rosin drying out

The chassis is mounted to the front of the radio with a tuning gang on each side (C1 & C2). There are two compartments on the front of the case which each store half the required batteries. The original set was powered from six A batteries (1.5V each), two or four B batteries (45V/22.5V), and one C battery (4.5V) to provide negative grid bias. While the set is shown with an external loop antenna in the lead photograph, there is an internal antenna located on the rear of the case. It is possible to attach a handle to the top of the set for carrying, but the weight makes this somewhat prohibitive.



The back of the chassis shows the connections made from the catacomb. The purple-labelled components above the tuning gangs are Karas Harmonik high-impedance audio transformers which were tested as replacements for T1 & T2.

over time and causing the rosin to crack as it shrank, breaking fine wires. I resoldered these into place using the newly-acquired circuit diagram as a guide, along with a certain amount of deduction.

No retuning was necessary because the IF transformers had fixed tuning using mica capacitors, and the incoming RF and oscillator output were separately hand-tuned from the front panel.

All of the RF inductors, except for the oscillator coils, are recessed into rectangular cut-outs in a laminated iron plate within the catacomb, and they also have laminated iron cores. The audio coupling transformers are also mounted within.

The AR-812 also has an internal aerial wound on a thin timber frame encircling the rear of the chassis compartment. There is a simple switch mounted on the inside rear of the case to switch between the internal frame aerial and an external long wire aerial. There are also two drawer-like compartments at the front of the set to house the dry cell batteries, one on each side of the main chassis compartment.

Originally, three large single cells producing 1.5V each were connected in series in each compartment, and these batteries were then connected in parallel to give a total voltage of 4.5V for the A supply to heat the filaments of the valves.

Four 22.5V dry cell batteries, or two 45V batteries, were connected in series to provide 90V for the B+ supply to the plates of the valves.

A small three-cell, 4.5V tapped battery mounted in a pocket at the rear of the chassis compartment made up the C or bias battery.

With all of the internals reassembled, all UV199 valves in place and a final positive check for faults in the catacomb completed, I plugged a set of high-impedance (2000Ω) headphones into the speaker socket and set the speaker switch set to cut out the last two audio stages. I connected my trusty vintage radio power supply from *Electronics Australia* (March 1990) to supply the B voltage.

I prefer to use three alkaline D cells for the A supply via the dropping rheostat as there is less chance of damaging those precious filaments. I also make up a C bias battery by connecting three alkaline cells in series.

I connected a long aerial and a good Earth and switched it on but, you guessed it, I heard nothing on the headphones. It was all doom and gloom. But then, few restored radios work the first time.

After fiddling with this and that for a couple of cold frosty winter nights, I distinctly remember hearing a very faint whisper in the headphones. Eureka! Things could only get better, and they did; there was a reasonable signal detectable immediately after the detector, indicating that all was well with the RF section.

The audio from the audio stages was weak when using a horn speaker. These are usually sensitive and I tried several types, all of around 2000Ω DC resistance. The audio section is relatively simple and all voltages were around about what one would expect. I suspected that one or more of the valves might have had low emissions. I didn't have any known-good UV199 valves to swap in for testing.

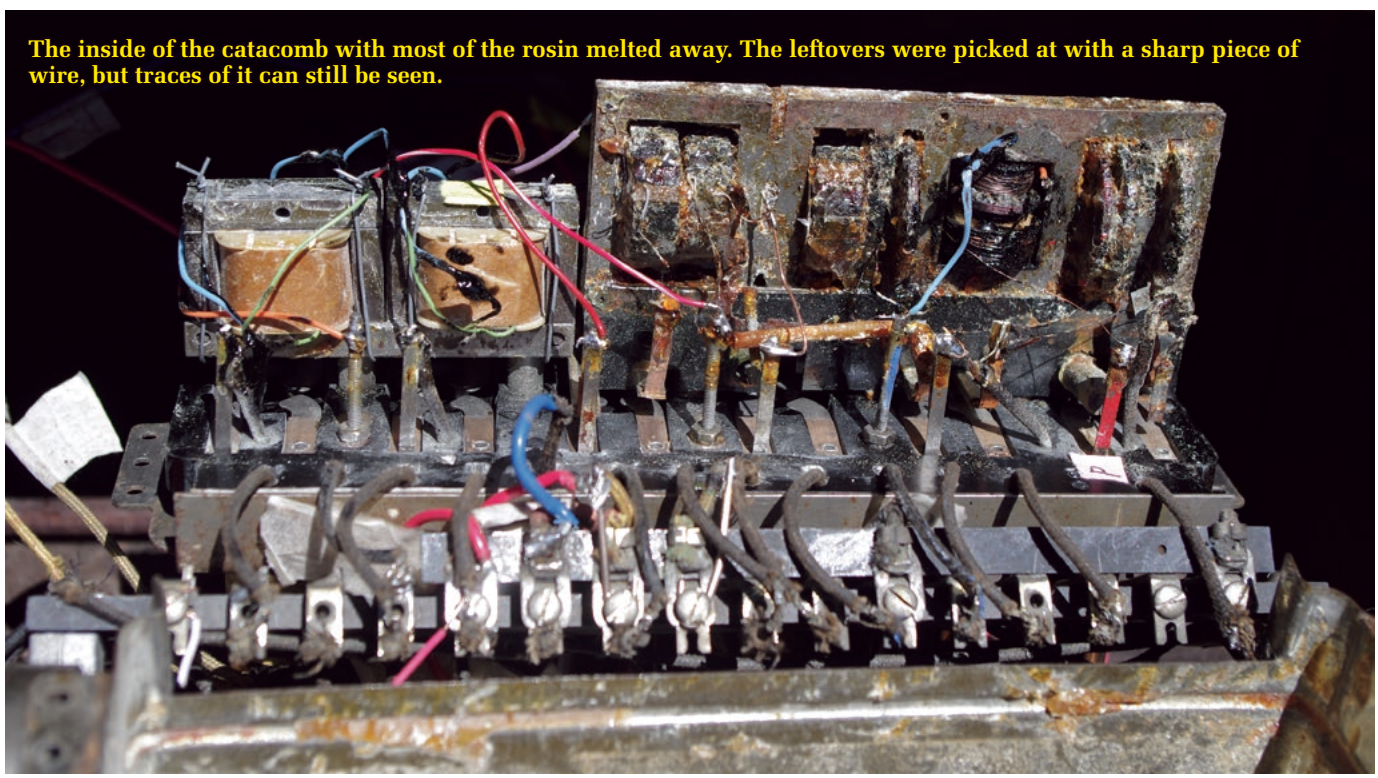
An opportunity presented itself a year or two later when rebuilding a Browning Drake receiver from about the same era. It was recommended that a UX199 valve was used in the first RF stage of this set to make neutralising easier.

I made up a socket to fit a UV199 and fitted it in parallel with the 201A or UX199 used in the Browning-Drake, so I could individually test my UV199s in the Drake.

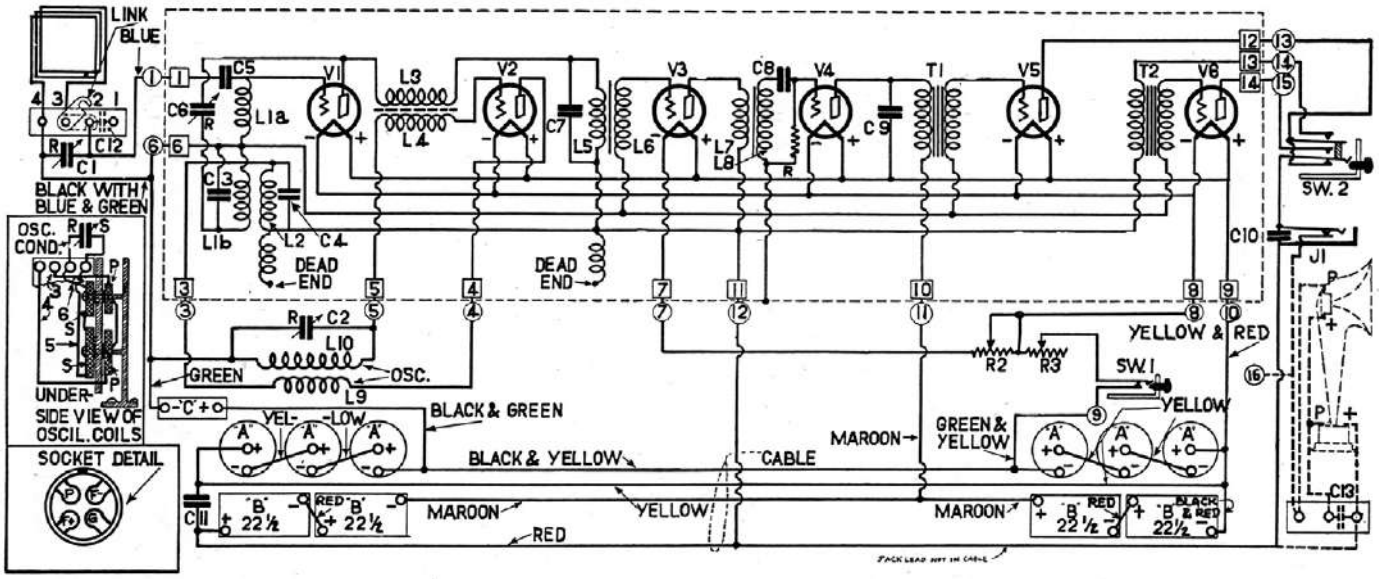
One of the UV199s from the RCA AR-812 Superhet proved to have reduced emissions, so I sought out a replacement valve, which improved the audio output considerably, but it was still quite weak.

AR-812 performance

Although the UV199 valves were



The inside of the catacomb with most of the rosin melted away. The leftovers were picked at with a sharp piece of wire, but traces of it can still be seen.



Here's an alternative version of the circuit diagram, taken from a service manual. This was included as a supplement to the following circuit diagram on page 102 as it more clearly shows all connections from filaments to HT etc.
Source: *www.rfcafe.com/references/radio-craft/radiolas-ar-810-812-radio-craft-june-1930.htm*

passable for RF amplification by 1924 standards, they were only used in the audio output stage because there were no better types available at the time. Audio amplification is not a role that these valves are well suited to.

Attempts to improve this situation were later made by fitting a special socket, which had to lay on its side to give clearance to the audio output socket, so a more suitable valve could be used. An extra HT battery was also required to provide the higher HT required for the audio valve.

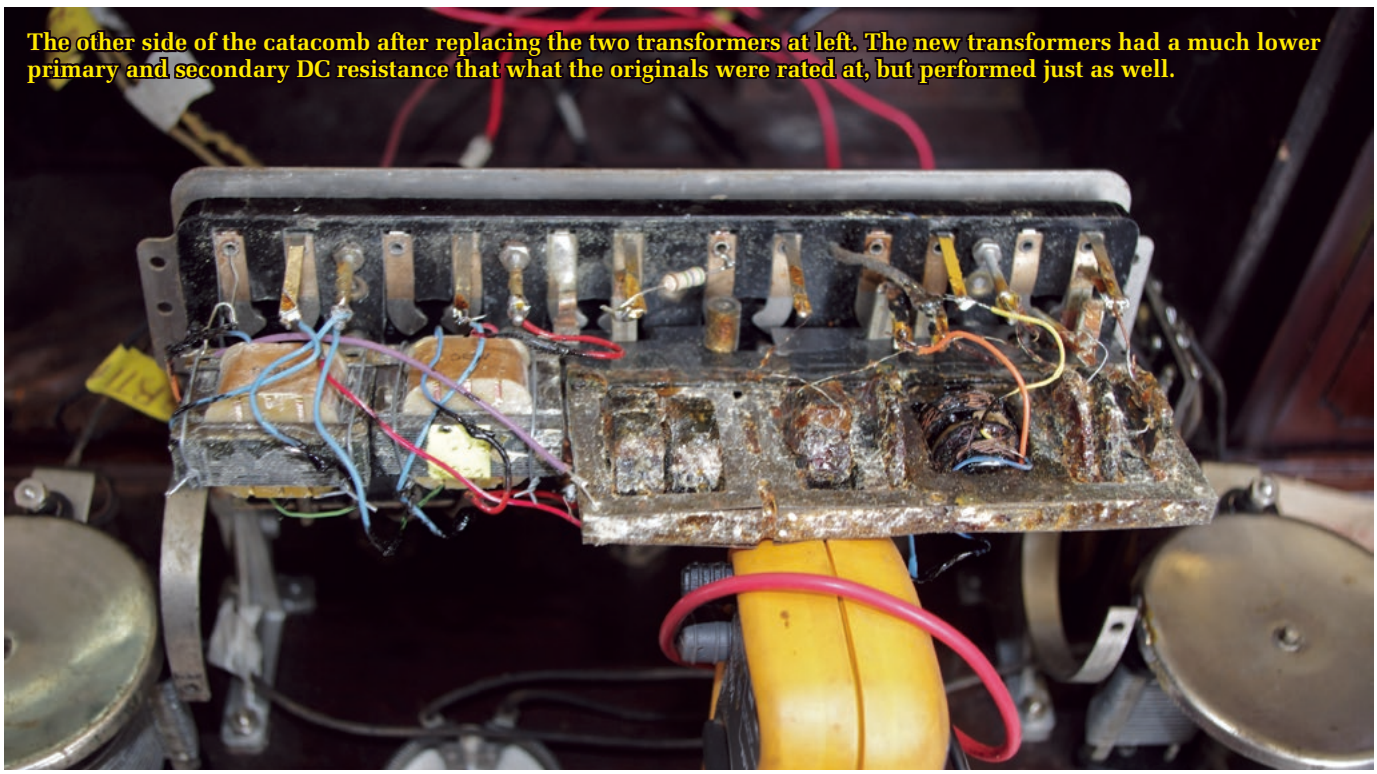
One advantage of the AR-812 is that it is very economical on battery power. The UV199 requires only 60mA for the heaters; only six valves are performing eight functions, achieved by reflexing two of the valves (ie, using them for both RF and AF amplification at the same time).

It is fairly easy to tune in stations and to operate the set. Stations are tuned in by using the oscillator dial on the right, which has excellent selectivity.

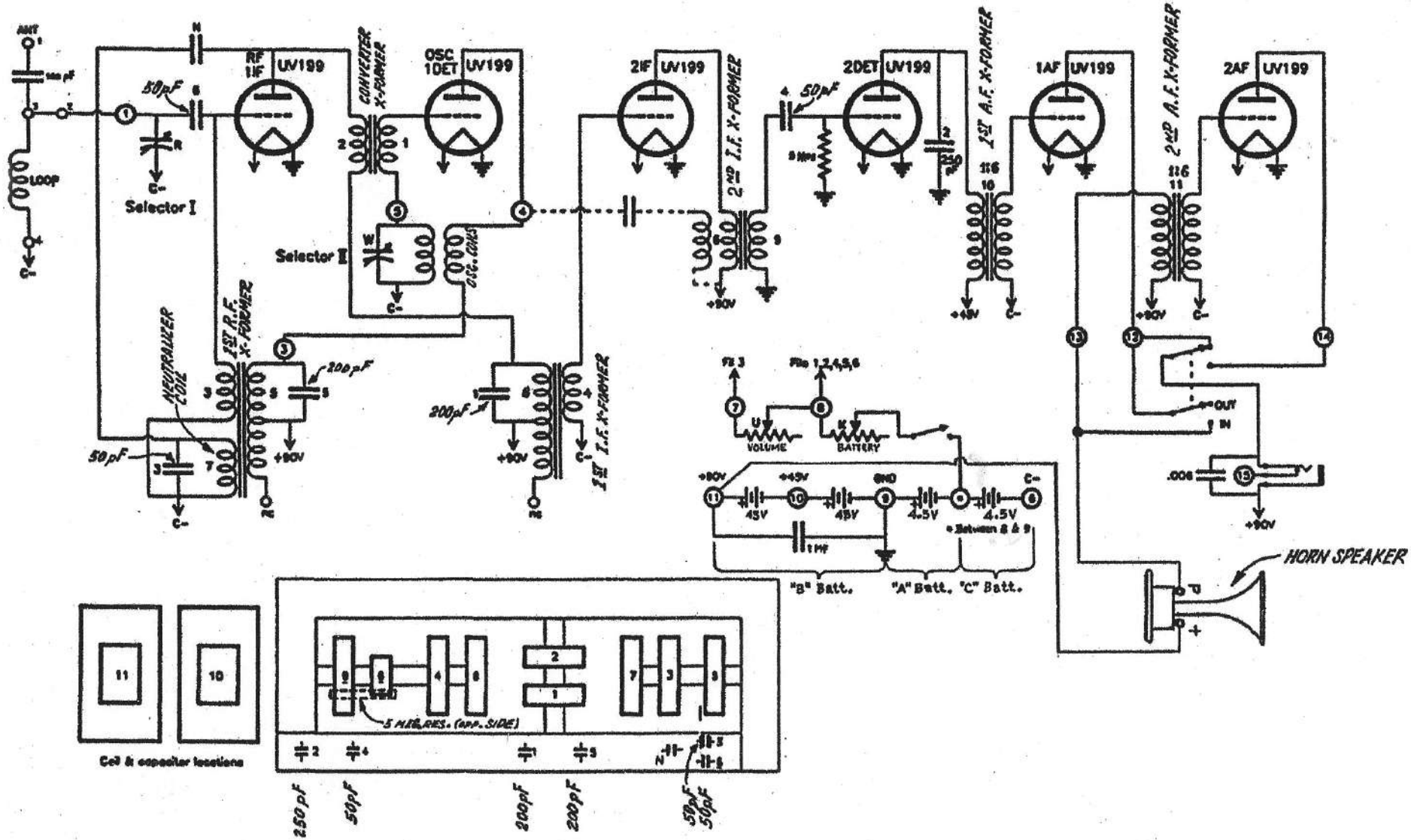
The dial on the left, used to tune the inbuilt aerial, has very broad tuning, making tuning in stations easy, especially once found and marked on the paper dial inserts provided with the set.

It is a good idea to back off the filament rheostat before switching off and to slowly turn it clockwise to increase the heater current after switch on until a comfortable (but not excessive) sound level is reached.

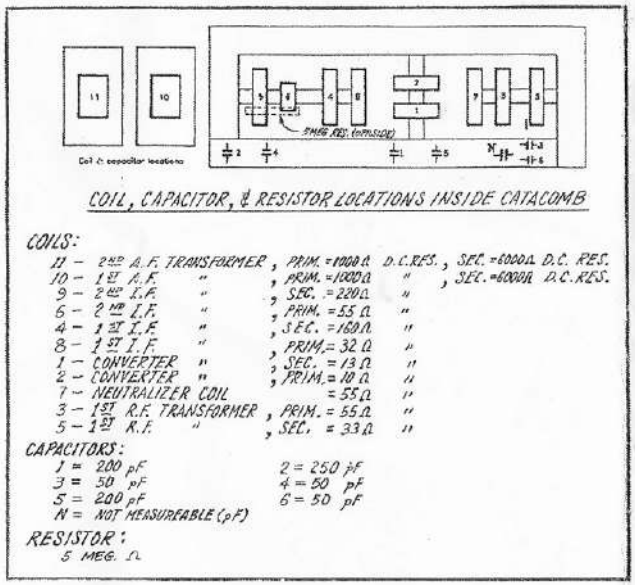
This avoids damage to the filaments



The other side of the catacomb after replacing the two transformers at left. The new transformers had a much lower primary and secondary DC resistance that what the originals were rated at, but performed just as well.



This circuit diagram was drawn by Alan Douglas using a program called TANGO, and is reproduced here from a scan. The RCA AR-812 is a reflex receiver and one of the first superheterodyne sets. Each valve in the AR-812 has quite a low current draw of ~60mA, which is why this circuit can be powered from dry cells. RF amplifier V1 is reflexed to function as an IF amplifier, while V2 performs as both the local oscillator and mixed (first detector), meaning the circuit effectively has eight stages. V3 is used for further IF amplfication, V4 is the second detector and V5/V6 are both used for AF amplification. The set uses a fairly low IF frequency of 45kHz, although some documents indicate it being as low as 40kHz and as high as 50kHz. Some versions of this circuit have the two transformers connected to the grid of V5 and V6 with a turns ratio of 1:3; this circuit has a ratio of 1:6 which matches the service manual. A wave trap may be needed for local stations as they can come in at multiple places due to the set's design. A cleaner version of the circuit can be found at https://antiqueradios.com/gallery/main.php?g2_itemId=48147 on the second page, but it does have some slight differences to the circuit shown above.


COIL, CAPACITOR, & RESISTOR LOCATIONS INSIDE CATACOMB
COILS:
11 – 2ND A.F. TRANSFORMER , PRIM. = 1000Ω D.C.RES. , SEC. = 6000Ω D.C. RES.
10 – 1ST A.F. " , PRIM. = 1000Ω " , SEC. = 6000Ω D.C.RES.
9 – 2ND I.F. " , SEC. = 220Ω "
6 – 2ND I.F. " , PRIM. = 55 Ω "
4 – 1ST I.F. " , SEC. = 150Ω "
8 – 1ST I.F. " , PRIM. = 32 Ω "
1 – CONVERTER " , SEC. = 13 Ω "
2 – CONVERTER " , PRIM. = 10 Ω "
7 – NEUTRALIZER COIL = 55Ω "
3 – 1ST R.F. TRANSFORMER , PRIM. = 55Ω "
5 – 1ST R.F. " , SEC. = 33Ω "
CAPACITORS:
1 = 200 pF 2 = 250 pF
3 = 50 pF 4 = 50 pF
5 = 200 pF 6 = 50 pF
N = NOT MEASUREABLE (pF)
RESISTOR:
5 MEG. Ω

TEST VALUES

From Terminal No.	To		Should Test
1	Grid of 1st socket		Open ✓
12	Terminal 3	(33 Ω)	Closed 26
12	P of 1st socket	(42 Ω)	Closed 30
12	P of 3rd socket	(55 Ω)	Closed 60
15	P of 6th socket	(SHORT)	Closed ✓
12	Terminal 14	(1000 Ω)	Closed 1400
4	P of 2nd socket	(SHORT)	Closed ✓
5	G of 2nd socket	(13 Ω)	Closed 12
6	P of 1st socket		Open ✓
6	G of 1st socket	(55 Ω)	Closed 40
6	G of 3rd socket	(160 Ω)	Closed 150+F
6	G of 5th socket	(6000 Ω)	Closed—weak click in phones
6	G of 6th socket	(6000 Ω)	Closed—weak click in phones
7	— F of 3rd socket	(SHORT)	Closed ✓
8	— F of 1, 2, 4, 5, 6, socket		Closed ✓
10	P of 4th socket		Open 150K
10	Catacomb Can	(SHORT)	Closed ✓
10	All + F	(SHORT)	Closed ✓
10	G of 4th socket	(4 to 5 Meg Ω)	Open ✓
11	P of 4th socket	(1000 Ω)	Closed 250
13	P of 5th socket	(SHORT)	Closed ✓
15	P of 6th socket	(SHORT)	Closed ✓

P -F G

Connection diagram (left) and continuity test (right) for the catacomb.

by overheating, which can cause the thorium coating, which improves cathode emissions, to boil off.

While this set's performance isn't high by today's standards, it would have been pretty good when it was released nearly 100 years ago!

Putting it in historical context

I have the AR-812 set up and working as I write this, and I can say that it is now performing well. Apart from the sound from the large horn speaker being sibilant and metallic, it's at least as good as a smaller transistor set on local stations, considering the limitations of their small speakers.

One can imagine a family crowding closely around the set, listening in a medium-sized room, but there is still a little to spare because although I have the volume control full on, I do like to back off the filament rheostat to lengthen the life of the valve filaments.

There were once claims of coast-to-coast reception in the USA, but I can't substantiate that performance. It is possible to receive some of the stronger Melbourne stations at night here in Hobart, although they come in weakly.

After all, this set uses very low gain valves (with a theoretical gain of about five times) and there is no RF amplification in the front end; this results in noticeably louder reception at night.

I have another example of an early superhet, an Ultradyne L2 from 1925. Robert Emile Lacault's Ultradyne L1 came on the market late in 1924, and as far as I can tell, it was the second superhet available to the public.

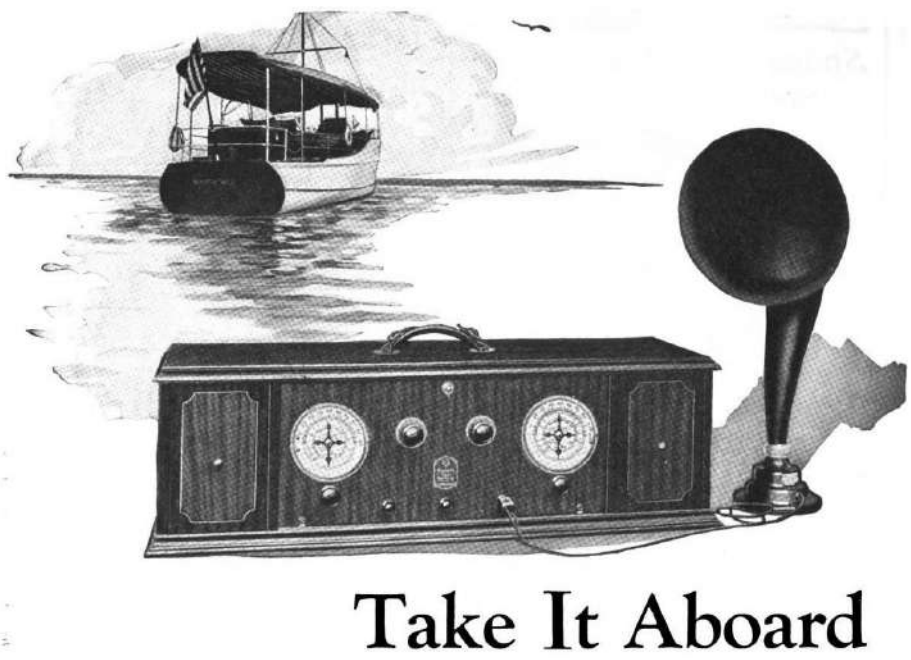
The set's layout is very different, with the Ultradyne being more conventional and an excellent performer for its time. This Ultradyne set uses eight UX201A four-pin triodes.

I also have a 1927 RCA Radiola 60 which was probably the first mains-powered superhet, using then-new five-pin screen-grid tetrode valves and single point tuning. This set gives much better performance than the first battery-powered, cutting-edge superhets.

I also have several five- and six-valve TRF sets from the same era (also using 201As) which perform well on local AM transmissions.

It must be said that a set such as Major Edwin Howard Armstrong's AR-812 represented a great leap forward for radio in the early 1920s and superheterodyne receivers are still widely used today for AM reception.

The few remaining sets such as these should be restored to working order for the benefit of all those of us in the future who can appreciate the genius of their designers and inventors. SC



An advertisement for the AR-812 with its original horn speaker. The radio sold for US $269, without batteries; nearly the same price as a Ford Model T!

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PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Cont. (Oct-Dec10) SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)

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MICROMITE LCD BACKPACK V3 (CAT SC5082) *(AUG 19)*
KIT – includes PCB, programmed micros, 3.5in touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other **mandatory** on-board parts **$75.00**

Separate/Optional Components:
- 3.5-inch TFT LCD touchscreen (Cat SC5062) **$30.00**
- DHT22 temp/humidity sensor (Cat SC4150) **$7.50**
- BMP180 (Cat SC4343) **OR** BMP280 (Cat SC4595) temperature/pressure sensor **$5.00**
- BME280 temperature/pressure/humidity sensor (Cat SC4608) **$10.00**
- DS3231 real-time clock SOIC-16 IC (Cat SC5103) **$3.00**
- 23LC1024 1MB RAM (SOIC-8) (Cat SC5104) **$5.00**
- AT25SF041 512KB flash (SOIC-8) (Cat SC5105) **$1.50**
- 10µF 16V X7R through-hole capacitor (Cat SC5106) **$2.00**

GPS SPEEDO/CLOCK/VOLUME CONTROL *(JUN 19)*
- 1.3-inch 128x64 SSD1306-based blue OLED display module (Cat SC5026) **$15.00**
- laser-cut matte black acrylic case pieces (Cat SC4987) **$10.00**
- MCP4251-502E/P dual-digital potentiometer (Cat SC5052) **$3.00**

TOUCH & IR REMOTE CONTROL DIMMER *(FEB 19)*
- N-channel Mosfets Q1 & Q2 (SIHB15N60E) and two 4.7MΩ 3.5kV resistors (Cat SC4861) **$20.00**
- IRD1 (TSOP4136) and fresnel lens (IML0688) (Cat SC4862) **$10.00**

MOTION SENSING SWITCH (SMD VERSION) *(FEB 19)*
- Short form kit (includes PCB and all parts, except for the extension cable) (Cat SC4851) **$10.00**
- SW-18010P vibration sensor (S1) (Cat SC4852) **$1.00**

DAB+/FM/AM RADIO *(JAN 19)*
- Main PCB with IC1 pre-soldered **$60.00**
- Main PCB with IC1 and surrounding components (white box at top right) pre-soldered **$80.00**
- Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
- Laser-cut clear acrylic case pieces **$20.00**
- Set of extra SMD parts (contains most SMD parts except for the digital audio output) **$30.00**
- Extendable VHF whip antenna with SMA connector: 700mm (**$15.00**) and 465mm (**$10.00**)
- PCB-mounting SMA (**$2.50**), PAL (**$5.00**) and dual-horizontal RCA (**$2.50**) socket

SUPER DIGITAL SOUND EFFECTS KIT (CAT SC4658) *(AUG 18)*
PCB and all onboard parts (including optional ones) but no SD card, cell or battery holder **$40.00**

USB PORT PROTECTOR COMPLETE KIT (CAT SC4574) *(MAY 18)*
All parts including the PCB and a length of clear heatshrink tubing **$15.00**

PARTS FOR THE 6GHz+ TOUCHSCREEN FREQUENCY COUNTER *(OCT 17)*
- Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
- One ERA-2SM+ & one ADCH-80A+ (Cat SC1167; **two required**) **$15.00/pk.**

MICROBRIDGE COMPLETE KIT (CAT SC4264) *(MAY 17)*
PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) **$20.00**

VARIOUS MODULES & PARTS
- **ISD1820-based voice recorder / playback module (Junk Mail Repeller, AUG19)** **$4.00**
- 23LCV1024-I/P SRAM (DIP) and MCP73831T charger ICs (UHF Repeater, MAY19) **$11.50**
- MCP1700 3.3V LDO regulator (suitable for USB Mouse & Keyboard Adapator, FEB19) **$1.50**
- LM4865MX amplifier IC & LF50CV regulator (Tinnitus/Insomnia Killer, NOV18) **$10.00**
- 2.8-inch touchscreen LCD module with SD card socket (Tide Clock, JUL18) **$22.50**
- ESP-01 WiFi Module (El Cheapo Modules, Part 15, APR18) **$5.00**
- MC1496P double-balanced mixer IC (DIP-14) (AM Radio Transmitter, MAR18) **$2.50**
- WiFi Antennas with U.FL/IPX connectors (Water Tank Level Meter with WiFi, FEB18): 5dBi – **$12.50** ~ 2dBi (omnidirectional) – **$10.00**
- NRF24L01+PA+NA transceiver with SNA connector and antenna (El Cheapo 12, JAN18) **$5.00**
- WeMos D1 Arduino-compatible boards with WiFi (SEPT17, FEB18): ThingSpeak data logger – **$10.00** ~ WiFi Tank Level Meter (ext. antenna socket) – **$15.00**
- Geeetech Arduino MP3 shield (Arduino Music Player/Recorder, VS1053, JUL17) **$20.00**
- 1nF 1% MKP (5mm lead spacing) or ceramic capacitor (Wide-Range LC Meter, JUN18) **$2.50**
- MAX7219 LED controller boards (El Cheapo Modules, Part 7, JUN17): 8x8 red SMD/DIP matrix display – **$5.00** ~ red 8-digit 7-segment display – **$7.50**
- AD9833 DDS module (with gain control) (for Micromite DDS, APR17) **$25.00**
- AD9833 DDS module (no gain control) (El Cheapo Modules, Part 6, APR17) **$15.00**
- CP2102 USB-UART bridge **$5.00**
- microSD card adaptor (El Cheapo Modules, Part 3, JAN17) **$2.50**
- DS3231 real-time clock module with mounting spacers and screws (El Cheapo, OCT16) **$5.00**

THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop

*Prices valid for month of magazine issue only. All prices in Australian dollars and include GST where applicable. **# P&P prices are within Australia. O'seas? Place an order on our website for an accurate quote.**

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB ONLY. If you want a kit, check our store or contact the kit suppliers advertising in this issue. For unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the Silicon Chip Online Shop has boards going back to 2001 and beyond. For a complete list of available PCBs etc, go to siliconchip.com.au/shop/8 Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30.00/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	SC2892	$25.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017	SC4281	$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
3-WAY ADJUSTABLE ACTIVE CROSSOVER CASE PIECES	SEPT 2017	SC4403	$10.00
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017	SC4444	$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017	SC4464	$25.00
THEREMIN	JAN 2018	23112171	$12.50
PROPORTIONAL FAN SPEED CONTROLLER	JAN 2018	05111171	$2.50
WATER TANK LEVEL METER (INCLUDING HEADERS)	FEB 2018	21110171	$7.50
10-LED BARAGRAPH	FEB 2018	04101181	$7.50
10-LED BARAGRAPH SIGNAL PROCESSING	FEB 2018	04101182	$5.00
TRIAC-BASED MAINS MOTOR SPEED CONTROLLER	MAR 2018	10102181	$10.00
VINTAGE TV A/V MODULATOR	MAR 2018	02104181	$7.50
AM RADIO TRANSMITTER	MAR 2018	06101181	$7.50
HEATER CONTROLLER	APR 2018	10104181	$10.00
DELUXE FREQUENCY SWITCH	MAY 2018	05104181	$7.50
USB PORT PROTECTOR	MAY 2018	07105181	$2.50
2 x 12V BATTERY BALANCER	MAY 2018	14106181	$2.50
USB FLEXITIMER	JUNE 2018	19106181	$7.50
WIDE-RANGE LC METER	JUNE 2018	04106181	$5.00
WIDE-RANGE LC METER (INCLUDING HEADERS)	JUNE 2018	SC4618	$7.50
WIDE-RANGE LC METER CLEAR CASE PIECES	JUNE 2018	SC4609	$7.50
TEMPERATURE SWITCH MK2	JUNE 2018	05105181	$7.50
LiFePO4 UPS CONTROL SHIELD	JUNE 2018	11106181	$5.00
RASPBERRY PI TOUCHSCREEN ADAPTOR (TIDE CLOCK)	JULY 2018	24108181	$5.00
RECURRING EVENT REMINDER	JULY 2018	19107181	$5.00
BRAINWAVE MONITOR (EEG)	AUG 2018	25107181	$10.00
SUPER DIGITAL SOUND EFFECTS	AUG 2018	01107181	$2.50
DOOR ALARM	AUG 2018	03107181	$5.00
STEAM WHISTLE / DIESEL HORN	SEPT 2018	09106181	$5.00
DCC PROGRAMMER	OCT 2018	09107181	$5.00
DCC PROGRAMMER (INCLUDING HEADERS)	OCT 2018	09107181	$7.50
OPTO-ISOLATED RELAY (WITH EXTENSION BOARDS)	OCT 2018	10107181/2	$7.50
GPS-SYNCHED FREQUENCY REFERENCE	NOV 2018	04107181	$7.50
LED CHRISTMAS TREE	NOV 2018	16107181	$5.00
DIGITAL INTERFACE MODULE	NOV 2018	16107182	$2.50
TINNITUS/INSOMNIA KILLER (JAYCAR VERSION)	NOV 2018	01110181	$5.00
TINNITUS/INSOMNIA KILLER (ALTRONICS VERSION)	NOV 2018	01110182	$5.00
HIGH-SENSITIVITY MAGNETOMETER	DEC 2018	04101011	$12.50
USELESS BOX	DEC 2018	08111181	$7.50
FOUR-CHANNEL DC FAN & PUMP CONTROLLER	DEC 2018	05108181	$5.00
ATtiny816 DEVELOPMENT/BREAKOUT BOARD	JAN 2019	24110181	$5.00
ISOLATED SERIAL LINK	JAN 2019	24107181	$5.00
DAB+/FM/AM RADIO	JAN 2019	06112181	$15.00
TOUCH & IR REMOTE CONTROL DIMMER MAIN PCB	FEB 2019	10111191	$10.00
REMOTE CONTROL DIMMER MOUNTING PLATE	FEB 2019	10111192	$10.00
REMOTE CONTROL DIMMER EXTENSION PCB	FEB 2019	10111193	$10.00
MOTION SENSING SWITCH (SMD) PCB	FEB 2019	05102191	$2.50
USB MOUSE AND KEYBOARD ADAPTOR PCB	FEB 2019	24311181	$5.00
REMOTE-CONTROLLED PREAMP WITH TONE CONTROL	MAR 2019	01111119	$25.00
PREAMP INPUT SELECTOR BOARD	MAR 2019	01111112	$15.00
PREAMP PUSHBUTTON BOARD	MAR 2019	01111113	$5.00
DIODE CURVE PLOTTER	MAR 2019	04112181	$7.50
FLIP-DOT COIL	APR 2019	19111181	$5.00
FLIP-DOT PIXEL (INCLUDES 16 PIXELS)	APR 2019	19111182	$5.00
FLIP-DOT FRAME (INCLUDES 8 FRAMES)	APR 2019	19111183	$5.00
FLIP-DOT DRIVER	APR 2019	19111184	$5.00
FLIP-DOT (SET OF ALL FOUR PCBS)	APR 2019	SC4950	$17.50
iCESTICK VGA ADAPTOR	APR 2019	02103191	$2.50
UHF DATA REPEATER	MAY 2019	15004191	$10.00
AMPLIFIER BRIDGE ADAPTOR	MAY 2019	01105191	$5.00
3.5-INCH SERIAL LCD ADAPTOR FOR ARDUINO	MAY 2019	24111181	$5.00
DSP CROSSOVER/EQUALISER ADC BOARD	MAY 2019	01106191	$7.50
DSP CROSSOVER/EQUALISER DAC BOARD	MAY 2019	01106192	$7.50
DSP CROSSOVER/EQUALISER CPU BOARD	MAY 2019	01106193	$5.00
DSP CROSSOVER/EQUALISER PSU BOARD	MAY 2019	01106194	$7.50
DSP CROSSOVER/EQUALISER CONTROL BOARD	MAY 2019	01106195	$5.00
DSP CROSSOVER/EQUALISER LCD ADAPTOR	MAY 2019	01106196	$2.50
DSP CROSSOVER (SET OF ALL BOARDS – TWO DAC)	MAY 2019	SC5023	$40.00
STEERING WHEEL CONTROL IR ADAPTOR	JUNE 2019	05105191	$5.00
GPS SPEEDO/CLOCK/VOLUME CONTROL	JUNE 2019	01104191	$7.50
RF SIGNAL GENERATOR	JUNE 2019	04106191	$15.00
RASPBERRY PI SPEECH SYNTHESIS/AUDIO	JULY 2019	01106191	$5.00
BATTERY ISOLATOR CONTROL BOARD	JULY 2019	05106191	$7.50
BATTERY ISOLATOR MOSFET BOARD (2oz)	JULY 2019	05106192	$10.00

NEW PCBs

MICROMITE LCD BACKPACK V3	**AUG 2019**	**07106191**	**$7.50**
CAR RADIO DIMMER ADAPTOR/VOLTAGE INTERCEPTOR	**AUG 2019**	**05107191**	**$5.00**
PSEUDO-RANDOM NUMBER GENERATOR (LFSR)	**AUG 2019**	**16106191**	**$5.00**

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ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Ferrite bead query

I'm just getting around to building the 6GHz+ Frequency Counter (October-December 2017; siliconchip.com.au/Series/319). My question relates to the SMD ferrite bead (FB1) from the 5V regulated output of the LM2940 regulator. In the parts list, it is described as a "low-resistance SMD ferrite bead (3216/1206)".

I have attempted to calculate the inductance required ($L = X \div 2\pi f$), but I'm not sure what frequency constitutes noise so that I can get a value for the impedance. Also, I'm not sure what "low-resistance" means in this instance. Is 50Ω low enough? What sort of current rating should I select for? (P. E., via PE Magazine UK)

● We answered a similar query in the Ask Silicon Chip section of the January 2019 issue (on page 111), but this query brings up some potential misconceptions which we should address.

We don't think the inductance of the bead is relevant. Ferrite beads aren't inductors; while they do have a small inductance, and this will have some effect, they mainly work due to hysteresis losses in the ferrite material. This is the main cause of their rising impedance with frequency. If what we wanted was a low-value inductor, we could just use one – SMD inductors are available in the nH range.

To answer your question, look for a ferrite bead with a DC resistance well below 1Ω, and a reasonably high impedance at 100MHz (say, at least 100Ω). Beads with good RF attenuation and a DC resistance below 0.1Ω are readily available. The one mentioned by J. T. in the January issue is the Laird HI1206T161R-10, which is what we used in our prototypes. That's an excellent choice.

Note that ferrite beads also provide some impedance from eddy current losses; however, ferrite material has significantly lower eddy current losses than iron, which is one of the main reasons it's used for inductors despite its low saturation threshold. For more information on the mechanism by which ferrite beads work, see the paper at: siliconchip.com.au/link/aark

Where to get fonts for a graphical LCD

Having read Tim Blythman's article on Low-cost 3.5-inch LCDs for Arduino and Micromite (May 2019; siliconchip.com.au/Article/11629), I am building a readout for my weather station using an MCUFRIEND 2.8-inch TFT LCD shield with ILI9338 controller. It has a parallel interface but I am using (successfully) the Arduino Uno serial interface to transfer data to it.

However, I can't find the correct code to print the degree (°) symbol. I have searched a plethora of extended ASCII tables without success. Can you please point me in the right direction?

I enjoy the quality of Tim's contributions to Silicon Chip and look forward to many more. (B. R., North Maleny, Qld)

● Your project sounds interesting. Perhaps you can write it up for our Circuit Notebook section when you've finished!

Many of the fonts which we use for the touch panels come from the following website: siliconchip.com.au/link/aarl

Many of these fonts change the backtick symbol (` ASCII code 96, hex 0x60) to a degree symbol. You can test this for your font by putting the backtick symbol in your code (as though you wanted to display it on the screen), and if the font has this modification, it will render as a degree symbol instead.

The reason they do this is partially explained by the following quote from Wikipedia: "The degree sign was missing from the basic 7-bit ASCII set of 1963, but in 1987 the ISO/IEC 8859 standard introduced it at position 0xB0 (176 decimal) in the Latin-1 variant."

Many microcontroller fonts only include ASCII characters from code 32 (space) to code 126 (tilde), to save space; therefore, they do not include the degree symbol. But since the apostrophe (code 39) and back-tick (code 96) are so similar in appearance, it is thought more useful to replace backtick with the missing degree symbol.

If your fonts do not take this approach, it's possible to modify them yourself, either by manually changing the font definitions or by using an online tool, such as the one at: siliconchip.com.au/link/aarm

Increasing Ultra-Low-Noise Preamp gain

I really enjoy reading Silicon Chip magazine. I like having online access to my subscription, especially for looking at past articles and projects.

I recently completed the Ultra-Low-Noise Remote Controlled Stereo Preamplifier (March-April 2019; siliconchip.com.au/Series/333) and built it with two SC200 modules, a power supply and speaker protector etc to make a complete amplifier. It works very well after fixing a couple of minor errors by the constructor (ie, me).

But I would like to have a little bit more gain from the preamp to allow for some signal sources that produce quite low signal levels. I think this could be solved by increasing the gain of the first op amp to 2.3-2.4 times instead of two times.

I think that this could be achieved by increasing the feedback resistor from 2.2kΩ to approximately 3kΩ, ie, the resistor between pins 1 & 2 of IC1a (the first op amp following the input to the preamp). Would this be workable and not affect things too much? Or should I modify something else to slightly increase the gain as desired? Thank you. (P. McG., Loftus, NSW)

● Yes, you can change the 2.2kΩ feedback resistor between pins 1 and 2 of IC1a and IC2a to get more gain. Since your suggested value of 3kΩ is not that much higher than the specified 2.2kΩ, the 470pF capacitor also across these pins would not require changing in value; the resulting high-frequency roll-off would still be well

above 20kHz.

Note though that if you were to increase these resistor values much more than that, you should ideally also reduce the parallel capacitor values proportionally. So for example, if you used 4.7kΩ feedback resistors, increasing the gain to around 4.3 times, you should then reduce the parallel capacitors to around 220pF (ie, 470pF × 2.2kΩ ÷ 4.7kΩ) to keep the frequency response the same.

Using a VOX to pick up mobile ringtone

I was just reading through an article in the July 2011 issue of Silicon Chip magazine on building a VOX (Voice-Activated Switch; siliconchip.com.au/Article/1101). This piqued my interest, as I have been searching for a way to use a mobile phone to activate a remotely controlled security device on our rural property.

I could build the VOX with an electret microphone to pick up the ringtone, but I want to avoid revealing the position of the phone. The article states that the device will accept an audio signal through a 3.5mm jack. Would this include a ringtone signal from the phone's headphone output? (K. W., Hamilton, NZ)

● Yes, you can use the ringtone sound to trigger the VOX via the 3.5mm jack plug connection from the phone to the VOX's 3.5mm jack socket input. No modifications are required. Just adjust the sensitivity for reliable detection and the delay according to your requirements.

10Ω resistors in Ultra-Low-Noise Preamp

In your articles on the Ultra-low-noise Remote Controlled Stereo Preamp in the March 2019 issue (siliconchip.com.au/Series/333), on page 38, there are two 10Ω resistors marked with asterisks, and next to them it says "* see text". But I can't find any mention of these resistors in the text.

A friend has pointed out that the 10Ω resistors are shown in the circuit diagram, Fig.7, on page 33, just to the left of CON5. They are connected between the 0V terminal of CON5, the power supply input, and the grounds for the left and right channels. He says that they are a standard anti-ground loop measure and that they isolate the RCA grounds from chassis ground.

Perhaps other readers would be interested in this explanation. Also, I enquired with element14 about obtaining the specified MKP capacitors (Cat 1005988 & 1519289), but they add a $20.00 freight charge to the total which cannot be waived.

Thanks for an excellent magazine. (J. C., Chelsea, Vic)

● Yes, as your friend said, the 10Ω resistors are included to minimise ground loop current. Any small ground voltage differences can cause a significant current flow unless the resistance between the ground points is increased. This can also lead to hum being injected into the signals.

The 47pF and 470pF capacitors can be C0G/NP0 ceramic, MKT polyester or MKP polypropylene. RS components sell a 470pF MKP type (see siliconchip.com.au/link/aarn, RS Cat 484-2016). Their delivery is free for online orders. Most 47pF ceramic capacitors are C0G/NP0, including those sold by Jaycar.

How to fix remote with worn contacts

In the 1980s, I purchased a Panasonic SG-HM 42 stereo system. After a few years, the remote packed up, I pulled it apart and discovered a small device that looked like a capacitor, marked "3.3". It had not been soldered properly; it had dry joints on both leads. I tried replacing it with a 3.3µF capacitor, but the remote wouldn't work. I then swapped back the original part, fixing up the solder joints, and it worked a treat.

The remote now refuses to work reliably. I discovered that the carbon contacts have worn off the most-used buttons. I tried shorting the buttons out but that doesn't work.

I tried about 10 different universal remotes but none worked. I finally found one that does work, but all it will do is switch the stereo on and off.

It seems to me that the carbon pads act as low-value resistors which are connected when the buttons are pressed. I tried replacing them with relays but this caused the buttons to trigger different functions.

I saw a complete remote for sale in

Pushbutton flip-flop relay control circuit wanted

I need a circuit for a bi-stable flip-flop multivibrator, but I haven't been all that successful in finding one online.

I am after a circuit which I can toggle on and off from a single (preferably) normally open pushbutton switch. It would be ideal if this switch could be connected between the positive rail and the input of the circuit and if the circuit could run from a 12V supply.

The flip-flop needs to be able to drive a relay. That way, I can use one button push to turn it on, and another button push to turn it off. I have no problem making a flip-flop that has two inputs, one to turn it on and one to turn it off, but the single input design eludes me. A discrete circuit would be my preference, but I'm not against using an IC. (P. W., Pukekohe, NZ)

● You can find a notional circuit which does what you want on page 11 of the Texas Instruments CD4013B data sheet (Figure 9, "Power Button Circuit", www.ti.com/lit/gpn/CD4013B).

In that circuit, the first IC (SN74LVC1G17) is simply a Schmitt-trigger inverter used to debounce the switch. You can use any Schmitt trigger inverter in its place, such as the 74C14, which will run from a 12V supply.

The second IC can be any version of the 4013B dual D-type flip-flop, including the Texas Instruments version, and these can also run from a 12V supply.

The Q output can't drive a relay directly, but it can drive the base of an NPN transistor via a 3.3kΩ resistor.

For example, you could use a BC337 and connect its emitter to 0V and its collector to the negative end of the 12V relay coil.

Add a 1N4004 diode between its collector and the 12V supply, with the anode to the collector. The positive end of the relay coil then goes to +12V.

the UK for $50 but purchasing it looks like a bit of a chore. Can you recommend a replacement remote control to me? (M. M., Croydon Park, SA)

● It is unlikely that any universal remote control would be suitable for a system from the 1980s, as it likely uses an outdated protocol. It should be possible to restore the switch contacts on the remote.

If you search the web for "restoring switch contacts on remote", you will find restoration kits to re-make the carbon paint contacts. One recommended method is to use vehicle demister conductive paint.

If that doesn't work, we suggest that you follow up the replacement remote that you saw on the internet from the UK.

Using Altronics drivers for bass guitar

I have bitten the bullet and ordered some 'proper' Celestion guitar drivers (Seventy 80s) for Allan Linton-Smith's Dipole Guitar speaker design (September 2018; **siliconchip.com.au/Article/11223**).

However, I want to try using two Altronics C3070 drivers for a bass guitar and would like to design a reflex or sealed enclosure to suit their Thiele/Small parameters. They are inexpensive, sensitive (95dB @ 1W/1m) and rated at 100W. And I bought two for the A-frame project before getting the Celestion drivers, so I have a vested interest in using them!

I have a five-string bass with a bottom E string, so it needs to have a reasonable response down to 30Hz. I am fully aware of the need to protect the drivers from subsonic transients with a high-pass filter etc, as otherwise, vented speakers are especially prone to death by bass guitar!

I heard of a program called Bass Box years ago; is that what you used to design the wonderful Majestic speakers? I would very much appreciate Allan's advice. (J. E., Thornleigh, NSW)

● Allan Linton-Smith replies: The speaker choice depends a lot on the bass player, the amplifier and the settings used. In my experience, speakers used by guitar players are easily wrecked because of the huge amount of distorted signal (ie, square waves) the players like to produce.

Purpose-built guitar speaker drivers such as the Celestion Seventy 80 are designed to handle a lot of abuse, whereas hifi drivers are much more delicate.

The Altronics C3070 drivers are worth a try, but their resonance frequency is quite low. For bass guitar work, they would be ideally housed in the recommended 35 litre sealed enclosure because otherwise, their x max (cone excursion) could be easily exceeded and cause permanent damage if heavy transients occur, especially with a powerful DC-coupled amplifier.

The high-pass filter you mention, set at 25Hz, will give a little bit of insurance but damage can still happen easily at much higher frequencies.

Otherwise, you might carefully try Altronics' recommended 40 litre box with a 500x35mm port. The ported version might not be liked by some bass guitarists, because it could produce a "muddy" sound.

I have no experience with Bass Box software. I suggest that you use the following website for a rough estimate of your box design: **siliconchip.com.au/link/aaro**

Using light chaser to trigger sound playback

As a member of a flying club, we have assembled a non-flying educational display aircraft for kids to sit in and play with the controls etc. I wish to record air traffic control phrases that will play when the kids activate dashboard switches.

I want to use cheap and easy-to-obtain greeting card digital voice recorder/player modules to play the phrases when the user activates a momentary switch. I want to use a number of these (5 to 10) with different phrases, but don't want more than one to play at a time.

Is there a simple circuit that will switch/activate one player at a time (per momentary switch press)? Ideally, there would be a time delay between switching to prevent a new phrase from playing before the previous one is finished. (W. L., Oakey, Qld)

● We suggest that you use the Light Chaser project from Short Circuits 3 (originally all designed by Silicon Chip). Jaycar have a kit for this, Cat KJ8064 (see **siliconchip.com.au/link/aarp**). This can be used to play each track in sequence.

There is a link to a PDF version of the Short Circuits 3 book on the Jaycar website, at the link above. You can see the relevant circuit on page 45 of that PDF.

You would leave off all the LEDs and use the collectors of Q1-Q5 to drive the trigger inputs of the voice recorder modules (presumably, the pushbuttons on these modules pull a pin low to trigger playback). If not, drive the coil of a 5V reed relay using transistors Q1-Q5 and solder its NO and COM contacts across the trigger switches.

You will also need to adjust the 555 timer (IC1) rate to make it slower. A 10µF capacitor at pin 2 (instead of 2.2µF) and a 470kΩ resistor from pin 2 to pin 3 (instead of 22kΩ) will give about 3s between each output.

To trigger the circuit with a pushbutton, break the connection from pin 6 of IC1 and connect a momentary pushbutton across the cut track (ie, one end to pin 6 and the other to the positive side of the timing capacitor). Add a 1MΩ pull-up resistor from pin 6 to pin 8 so that it won't trigger until that button is pressed.

That circuit as shown is suitable for triggering up to five modules. But the 4017 chip (IC2) has more outputs and could be expanded to drive up to 10 transistors. To do this, break the connection between pins 1 and 15 and tie reset pin 15 to 0V. You can then use pins 1, 5, 6, 9 and 11 to drive the added transistors, Q6-10. For more details, see the 4017B data sheet, available for download on the internet.

You might also want to look at the Junk Mail Repeller on page 48 of this issue as multiple of these devices could be used to play back various phrases.

DAB+ signal booster wanted

I have a Sangean DCR-89 DAB+ clock radio which has a short wire antenna at the rear of the case. The signal strength display shows a reasonable signal in the morning (about 50%), but at other times, the radio often drops out due to insufficient signal.

My house has a metal roof and I cannot easily install an external antenna. I have a VHF TV antenna which works well with digital TV. Would I be able to connect the radio antenna wire to the TV antenna in some way? I think the DAB+ transmitter is at the same location as the TV towers for Adelaide.

Have you published any indoor

DAB+ antenna boosters which I could build? How would I connect such a booster to the radio as there is no antenna socket, just the wire hanging out the back? (J. B., via email)

● We haven't published any DAB+ boosters, but since all DAB+ broadcasts in Australia use the VHF band III frequencies, which are shared with TV signals, you should be able to use a VHF antenna or booster designed for televisions with a DAB+ radio.

We don't recommend making a direct connection from an antenna socket to the antenna of a radio not designed to be driven by an external antenna. We suggest you connect the input of a VHF amplifier to your indoor antenna socket (via a splitter, if required) and then wire a small VHF antenna to its output, re-radiating the signal inside your house. This can then be picked up by the radio's existing antenna.

Questions about Touchscreen Clock Radio

June 2019 was another great issue of Silicon Chip magazine. The only problem is that I read it in two days! Great work, please keep it up.

I need a new clock radio, and the design by Dan Amos in that issue seems perfect.

I might re-use an enclosure from a discarded appliance, or I might build a housing out of timber or acrylic sheeting from a dumped flat screen monitor; the options are endless.

There are also literally hundreds of sound systems donated to recyclers at our relatively humble country tip, most with perfectly good speakers. Our tip shop is a veritable gold mine.

I ordered all the modules from the Silicon Chip Online Shop and they arrived in record quick time; great service from the Big Smoke!

I found numerous mounting options online for the TEA5767 receiver, which is helpful. But I have a few questions:

What type of capacitors and inductors should I use? And can I use a 5V coil relay controlled directly by the Micromite BackPack? (S. S., Barrington NSW)

● We suggest that you use MKT/MKP/greencaps as they are better than ceramics for coupling. That's because ceramics (except for C0G/NP0) have a very high voltage coefficient, which means they have a very non-linear response.

Ideally, the inductors should be air-cored, but that's a bit impractical at 300µH if you want to keep the unit compact.

We are not sure whether ferrite or powdered iron cores would be better in this role, but we would probably choose powdered iron as the resulting inductors will be smaller, and they do not saturate as easily which will hopefully mean that they have decent linearity.

You could use a 5V coil relay rather than a 12V relay, but it wouldn't save you any components and would probably draw more power.

That's because its coil power will be the same, but its supply current will have to flow through MOD4, which is not 100% efficient.

The only type of relay that can really be driven directly by a micro is a reed relay, but such relays won't have the current rating (2A+) necessary to power MOD5. And since that means you will still need a driver transistor, you might as well stick with the 12V relay specified in the original design.

Building a 24V battery charger and balancer

I have been searching past issues of Silicon Chip for a deep-cycle battery charger, to suit two 12V batteries of approximately 100Ah each which are charged from solar panels.

I may require a battery balancer. I want to build a solar-charged 24V DC household system to power various small devices.

I think I have seen an article in the magazine to this effect in the past, but

A suitable case for building a complete SC200 amplifier

I want to build a pair of SC200 power amplifier modules (January-May 2017; siliconchip.com.au/Series/308) with your Ultra Low Noise Remote Controlled Stereo Preamplifier (March & April 2019; siliconchip.com.au/Article/11442) into a nice metal case.

I was particularly impressed with the March 2012 article by Greg Swain on building a complete Ultra-LD Mk.3 stereo amplifier (siliconchip.com.au/Article/738), which incorporated a magnificent diagram of the inside of the finished amplifier showing all the various components and how to lay them out inside the chassis, giving an optimised layout and wiring.

Can you nominate a powdercoated chassis of the appropriate dimensions into which I can fit all the required circuit boards and components? And, if it is not prepunched, a drilling guide for the holes required? So far, the main reason I have not built an SC200-based amplifier is that I am uncertain how to build it into a suitable case which will give a good final presentation.

I am 82 years of age now and still soldering on. I have a perfectly good Cambridge Amplifier with a matching CD player but would like to have one that I built myself. (B. T., Rosebud, Vic)

● It's a pity that the case we used for the Ultra-LD Mk.3 amplifier is no longer available, as it would also be suitable for an SC200-based amp (the SC200 modules were deliberately designed to fit in the same spaces).

We suggest you consider using a Bud Industries rackmount case as used in our UPS project (see the May 2018 issue for details; siliconchip.com.au/Series/323).

They are available from Digi-Key (see advert on page 3) as separate components that you assemble, at a quite reasonable price. They're supplied as bare aluminium, but it wouldn't be difficult to spray paint them black (or white, or whatever other colour you want). Use good quality paint from your local hardware store and it should give a hard-wearing finish.

Unfortunately, you would need to drill and cut all the holes yourself, but aluminium is easy to work, and a little planning (eg, printing and attaching paper templates produced in a CAD program) can give excellent results.

I am unable to remember which issue it was in. (P. C., Ormiston, Qld)

● We published a 10A solar battery charger in the March 2012 issue (12/24V MPPT Solar Charge Controller; siliconchip.com.au/Article/749). That article includes a description of how to alter it to suit 24V systems. The PCB and other parts are available from our Online Shop (see siliconchip.com.au/Shop/8/820).

We have not published a suitable balancer yet, but we are considering designing one for 24V or 48V battery banks made up of 12V batteries (or multiple sets of 12V batteries in parallel).

Measuring wind turbine air pulses

Have you ever published a kit that is capable of measuring the strength of the pulses coming from the rotating blades of a wind turbine?

I was wondering if it would be possible to use a MAP sensor from a car, as these are quite sensitive and are easy to get.

I am about to be surrounded by 53 towers with a height that equals the Realto Tower in Melbourne, producing a claimed 9.4MW each. These are to be erected in the forested area between Yinnar, Boolarra and Mirboo North.

I have read of problems with the pressure pulses caused by the blades causing all sorts of adverse effects on peoples' health, and I would like to get some pressure measurements from the installation at Toora so that I can get an idea of what we are in for.

I fear that no amount of protest will avoid their installation, as our State Government is blind to the adverse effects that have been widely reported by reliable sources all over the world. (P. A., Gippsland, Vic)

● We haven't published such a project. However, we have published altimeters that could be modified for this purpose. They can discern changes in air pressure with a resolution of around 0.1hPa.

We published a Touchscreen Altimeter design in December 2017 (siliconchip.com.au/Article/10898) that could be used to monitor the air pressure with some software changes. It would need to be set up to sample rapidly and apply some sort of 'peak hold' algorithm so that you could reliably detect the maximum pressure variation.

We also published an analog altimeter design in the September-November 1991 issues. It used a pressure sensor and instrumentation amplifier, giving a voltage proportional to the pressure, that you could then measure. Copies of those back-issues can be ordered from the Silicon Chip Online Shop (siliconchip.com.au/Shop/5).

You may also want to take a look at our "Bad Vibes" Infrasound Snooper project from the June 2015 issue (siliconchip.com.au/Article/8600).

Capacitor Discharge Ignition kit wanted

I was just reading your article on the High-Energy Multi-Spark CDI for Performance Cars (December 2014 & January 2015; siliconchip.com.au/Series/279) and was wondering if a full kit is available. If so, does the transformer need winding or does it come pre-wound? (Dave, via email)

● There is no complete kit available for that project. But we do sell the hard-to-get parts, which includes most of the transformer components, all the ICs, the Mosfets and some other parts (siliconchip.com.au/Shop/20/2906). You will also need the PCB, which is available separately (siliconchip.com.au/Shop/8/2878).

The remaining parts are common and available from Jaycar and Altronics. You will need to wind the transformer, but it isn't difficult if you follow the instructions in the article.

If you still think it's beyond your abilities, check our Marketplace section, starting on page 111; there are a couple of people who advertise there, who can build kits for those who don't want to (or can't) do it themselves. SC

Connecting LEDs in series with a mains appliance

My son wants to have a red light (neon or LED) come on when he switches on an outside light. The problem is only an Active and return wire come to the switch; there is no Neutral wire. He suggested merely putting one LED in series with the wire from the switch to the light. I told him he'd blow the LED to smithereens, but, after further thought, I think it may be workable.

Assuming the light is 55W and has ~220V across it (to simplify the maths), it will draw an average of 250mA. So, a 10Ω 1W resistor in series with the light will have 2.5V across it.

A red LED (~1.7V forward voltage) with a 22Ω series resistor, connected across this, should light up OK. However, the LED will be on less than 50% of the time as the supply voltage is AC.

The resistor values would need changing if the bulb wattage changed. Will this work? Do you have a better idea, or have you published a circuit to do this? Is there a commercial switch available with an inbuilt LED? (J. B., Northgate, Qld)

● The main problem with using a resistor to providing a small dropping voltage in series with the lamp is that it may not survive the initial turn-on surge current, and it would probably explode spectacularly during even a brief short circuit in the lamp (as can happen, for example, when PAR bulbs blow).

Incandescent lamps have a very low cold resistance compared to when alight. And if the lamp is a compact fluorescent or LED type, these usually have an internal switchmode supply which also draws a large initial current as its capacitor(s) charge up.

Another way to derive a suitable voltage for LED driving is to use a few diodes in series, eg, 1N5404 (rated at 3A, 400V). You could use four; three in series in one direction, and one in the other, so that the lamp still receives an AC voltage. Connect the LED across the three diodes with a series resistor to set its operating LED current. Make sure it has the correct polarity.

The diodes will provide a reasonably fixed voltage for the LED, even if the lamp wattage varies, and will handle brief surges of tens of amps without failing.

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Coming up in Silicon Chip

4-axis Motorised Chair for Simulators
Motorised chairs can be used to increase realism in racing and flight simulators, but they're expensive. This article shows you how to build your own from scratch, including a Micromite-based motor controller interface which connects to your PC via USB and is compatible with a wide range of software.

Cyber-espionage and Cyber Weapons
This two-part series from Dr David Maddison is a window into the fascinating world of Cyber-espionage. The first part focuses on techniques which can be used to extract information from devices without the consent or knowledge of the operators, by exploiting hardware design flaws. It also includes a section on surreptitiously modifying electronic devices to spy on the operators.

Micromite Explore 28
This tiny module has the power of the 28-pin Micromite, but it also incorporates an onboard power supply, USB/serial interface and programming interface. Despite this, it's barely any larger than a 28-pin DIL package IC. And it's available as a kit or a pre-built module, so that you can get up and running (and programming in MMBasic) straight away.

Rechargeable LED bicycle light
This device uses a switchmode converter to drive a string of LEDs from a rechargeable lithium-ion battery pack. It has multiple light modes and automatically reduces the LED current to prevent overheating.

Universal 6-24V Battery Charge Controller
This revised Battery Charge Controller is more flexible than our previous designs. It turns a 'dumb' battery charger into a smart charger, suitable for use with various types of 6V, 12V or 24V batteries, including lead-acid, gel-cell, Li-ion and $LiFePO_4$ (lithium-ion phosphate). You can select between one of three preset charging profiles or one of three adjustable profiles, and choose between one, two or three-stage charging.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The September 2019 issue is due on sale in newsagents by Thursday, August 29th. Expect postal delivery of subscription copies in Australia between August 27th and September 13th.

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Notes & Errata

Versatile Trailing Edge Timmer, February-March 2019: the infrared remote control specified for this project (Little Bird SF-COM-14865) has been changed to emit different remote control codes. This new version looks slightly different from the original as it has dotted white circles around the buttons (see photo). If you have this version of the remote, you will need to use the revised version of the firmware (1011119B.HEX) which has been modified to expect the new set of remote control codes.

Low-power AM Transmitter, March 2018: on the PCB, the connections to pins 2 & 3 (D & S) of Mosfet Q3 have been swapped, rendering the reverse polarity protection inoperative. This has been fixed on the RevD PCB. For earlier PCB revisions, these pins should be bent and crossed over, with one insulated using a short length of heatshrink tubing or similar.

LifeSaver For Lithium & SLA Batteries, September 2013: in some cases, reverse leakage through the dual diode can affect the voltage at pin 3 of IC1, causing the voltage thresholds to be lower than expected and possibly preventing their adjustment via VR1. As this connection to the diode is not necessary for operation, constructors should cut the top-side track between VR1 and the diode (between VR1 and ZD1) or use a BAT54 diode rather than a BAT54C.

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CNC Machinery | Metal Working | Sheet Metal Fabrication | Wood Working | Workshop & Automotive | Lifting Handling | Cutting Tools | Machine Tool Accessories | Measuring Equipment

Handy Workshop Tips & Techniques - 1st Edition

- 324 coloured pages
- "Covers all you need to know about anything you need to do in your workshop"

$33 ~~$39~~ (L345)

Digital Caliper

- 150mm / 6"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$33 ~~$38.50~~ (M738)

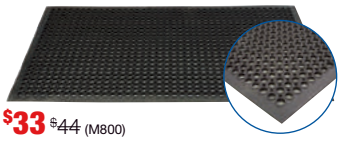
Digital Caliper

- 200mm / 8"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$44 ~~$59.40~~ (M739)

RFM-1500 Rubber Anti-Fatigue Mat

- 1505 x 905mm (8mm thick)
- Workshop or ute
- Tapered edge



$33 ~~$44~~ (M800)

CTG254 Contour Gauge

- 254mm length
- 45mm depth
- Magnetic side
- Impact resistant plastic

$22 ~~$26.40~~ (M967)

WHG-6 Digital Height Gauge

- 0 - 150mm measuring range
- Ideal for saw blades & routers
- DRO in mm, inches & fractions
- 0.01mm resolution
- Auto on & shut-off

$33 ~~$39.60~~ (W643)

EF-5S Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes case

$35 ~~$42.35~~ (F100)

RNB40 - Nut & Blind Riveter Set - 130 Piece

- Aluminium rivet nut inserts included: M5, M6, M8, M10 - (10ea)
- Blind aluminium rivets included: Ø3.2, Ø4.0, Ø4.8, Ø6.4mm (20ea)
- Inc. mandrel spanner & blow mould case

$119 ~~$132~~ (N001)

9" Drill Press Locking Clamp

- 2" jaw opening
- Quick release lever
- Swivelling jaw pad

$20 ~~$24.20~~ (C103)

HSS Countersink Set

- 6 piece set
- HSS M2 grade
- 45° angle
- Ø1.5 ~ Ø6.3mm
- Ø6.3 ~ Ø8.3mm
- Ø8.3 ~ Ø10.4mm
- Ø10.4 ~ Ø12.4mm
- Ø12.4 ~ Ø16.5mm
- Ø16.5 ~ Ø20.5mm

$69 ~~$82.50~~ (D1061)

HSS Sheet Metal Step Drill Set

- 3 piece set
- For drilling thin material
- HSS M2 grade
- 4-12mm x 1mm steps
- 6-20mm x 2mm steps
- 6-30mm x 2mm steps

$69 ~~$82.50~~ (D1071)

HS-2S Throatless Hand Lever Shear

- 1.2mm mild steel capacity
- Cast steel construction
- Tool steel quality blades
- Gear drive shearing action

$269 ~~$297~~ (S184)

PROMAX 200 - Auto Darken Welding Helmet

Weldclass

- Application: Mig & Arc & Grinding
- 9 ~ 13 adjustable shade
- 2 arc activation sensors
- Ultra clear vision with enhanced colour recognition
- Switching speed 0.00003 sec

$79 ~~$89~~ (W001)

VIPER ARC 140 - DC TIG & ARC Inverter Welder

UNIMIG

- 20 - 140 Amps
- Thermal overload protection
- Includes 2.5m arc leads
- 15% @ 140A duty cycle
- 240V / 10 amp

$199 ~~$214~~ (W165)

TiGer 2000S Wetstone Grinder

scheppach

- German design & technology
- 200mm stone & 225mm hone wheel
- 120rpm grinding stone speed
- 120W, 240V motor
- Includes straight edge jig, setting gauge & honing paste

$169 ~~$198~~ (W859)

bts 900x Belt & Disc Linisher Sander

scheppach

- 100 x 915mm belt
- Ø150mm disc
- Tilting table & mitre guide
- 370W 240V

$209 ~~$242~~ (L105)

STT-4W Service Tool Tray

- 740 x 510 x 20mm top tray
- 860~1200mm adjustable tray height
- 34kg tray load capacity
- Padded vertical support

$139 ~~$154~~ (T758)

MCW-40H Mechanics Creeper

- 1020 x 440 x 110mm
- Fabricated steel frame
- 3 position headrest
- 136kg weight capacity
- 6 swivel wheels

$44 ~~$55~~ (A005)

TJA-2S - Hydraulic Steel Trolley Jack & Axle Stands Package Deal

- Includes:
- 2T Trolley Jack (J021)
- 3T Axle Stands (A3435)
- Pick Up Tool (M0010)

ARMSTRONG Better by design

$279 ~~$341 RRP~~ (K105)

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